TERRA

THE NATURAL HISTORY
MUSEUM OF
LOS ANGELES COUNTY

VOLUME 28, NO. 4
SUMMER 1990

Fresh Fish Daily.

These fathead minnows aren't the catch of the day. They're important employees of Unocal's refinery in Rodeo, California, near San Francisco. They work in the bioassay lab. Their job is to help us assure the purity of treated waste water discharged into San Pablo Bay. State and federal regulations require a 50 percent survival rate in this water for 96 hours.

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TERRA

THE MEMBERS' MAGAZINE
OF THE
NATURAL HISTORY MUSEUM
OF LOS ANGELES COUNTY

VOLUME 28, NO. 4
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COVER: This California Condor chick is being fed by a hand puppet at the San Diego Wild Animal Park. For more information about efforts to save the condor, see the article by Lloyd Kiff, Natural History Museum Curator of Ornithology and Condor Recovery Team Leader, on page 6.
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FROM THE DIRECTOR

As press time for this special issue of TERRA approaches, ornithologists from all over the world are converging on Los Angeles for the first joint meeting of the American Ornithological Union and the Cooper Ornithological Society, the two largest professional ornithological organizations in America. With approximately 1,000 participants, including scientists from the U.S.S.R., Latin America, Australia, and the People's Republic of China, it is planned as the largest ornithological meeting ever held in the United States.

The meeting, which begins June 25, is co-hosted by the Natural History Museum of Los Angeles County, the UCLA Department of Biology, and the Western Foundation of Vertebrate Zoology.

Throughout the event there will be a strong emphasis on global conservation topics. The meeting features more than 400 scientific reports of significant advances in ornithology and symposia on special topics, including one on the disastrous effects of the illegal live bird trade on the world's parrot populations.

These meetings allow the Natural History Museum to show off its newly renovated collections facilities to ornithologists from around the world. But there are many other reasons why the Natural History Museum is particularly appropriate as a site for these meetings. One of the two societies meeting here, the Cooper Ornithological Union, was a founding body of the museum in 1913 (see Kimball L. Garrett's article on page 44 for more about this early association). Also, Dr. Ralph W. Schreiber, the late Curator of Ornithology to whom the museum's future Hall of Birds is dedicated, served as President of the Cooper Ornithology Union from 1983 to 1985; he was a Fellow and member of the governing council of the American Ornithological Union as well.

In addition, the museum's collections of bird specimens, eggs, and fossils are internationally significant. The museum's collections include representatives from 55 percent of the world's 9,000 bird species. The museum also administers the Western Foundation of Vertebrate Zoology, which houses the world's largest collections of bird eggs and nests and one of the largest ornithological libraries in North America. With natural habitats diminishing daily around the world, our bird collections take on an ever-increasing importance as we try to understand and learn from the diversity of life on this planet.

Craig C. Black
Director

STAFF NEWS

DR. CHARLES ROZAIRE RETIRES. The appointment of Dr. Charles Rozaire as Curator of Archaeology at the Natural History Museum was announced by then director Dr. Herbert Friedmann, on December 9, 1963. After twenty-six years in this position Dr. Rozaire has opted for early retirement (March 30, 1990), but will continue his writing and research as Curator Emeritus.

Charles Rozaire came to the museum from the Nevada State Museum, where he held a similar post. He specializes in the archaeology of the southwestern United States and Mexico and is an authority on prehistoric man and his culture from this area. As museum director Dr. Craig Black has stated, "there is no topic more central to the humanities than

MUSEUM ON THE MOVE

that concern with man's prehistory and the origins of social structure." Thus Charles Rozaire, with his knowledge and expertise in this area of concern, has been able to provide an important public function and at the same time greatly expand the museum's research program in the field.

A native of southern California, he studied at UCLA, where in 1949 he received his B.A. degree, his M.A. in 1952, and his Ph.D. in 1957. In additional to traditional staff duties performed as Curator of Archaeology at the Southwest Museum, Nevada State Museum, and our own museum, he has participated in scientific investigations for the Smithsonian Institution, the Peabody Museum at Harvard, Montana State Museum, and UCLA. He also been active in teaching at UCLA and California State University at Northridge.

Immediately upon his appointment as Curator of Archaeology at the Natural History Museum, Charles Rozaire embarked on the ambitious task of planning a new, permanent pre-Columbian exhibition. This exciting gallery was opened to enthusiastic acclaim in 1968. With the stimulating aid of the museum's Exhibits Division, Charles has just completed renovation of this gallery.

Charles Rozaire is a Fellow of two prestigious national organizations, the American Association for the Advancement of Science and the American Anthropological Association, as well as a member of six other leading professional societies. He has published around fifty scientific papers as well as authoring a widely acclaimed book, *Indian Basketry of Western North America*, published in 1977.

Charles Rozaire has succeeded in leaving a lasting imprint on the staff, the various boards, and the many friends of the museum. His friendliness and compassion have made him readily approachable by all those involved with the museum, and it is good to know that he will be around in case we need him.

Dr. Fred S. Truxal
Chief Curator Emeritus
Life Sciences Division

DON MEYER

A large realgar crystal recently donated to the museum.

NEW ACQUISITIONS

THE TOMO ITO COLLECTION. Tomo Ito (1909-1986) collected his first mineral specimens at the age of eight on his father's ranch near Riverside, California. Thus began an avocation that was to span nearly seven decades. His career as a mining geologist and metallurgist evolved out of his love of minerals. A scholarship to Stanford University led to a Bachelor of Science degree in Geology in 1932. He traveled widely in his profession, which afforded him the opportunity to add to his collection. It was his long-standing wish that his collection be given to the Natural History Museum of Los Angeles County upon his death. In January 1990 Tomo Ito's widow, Kimi S. Ito, donated his collection to the museum in his memory.

The Tomo Ito Collection is particularly notable for a fine suite of copper minerals from the Copper Queen mine in Bisbee, Arizona. The collection also includes many other unusual specimens, especially from deposits in Arizona, California, and Mexico. A selection of specimens from this collection is currently on display at the entrance to the Hall of Gems and Minerals.

OTHER NOTABLE MINERAL ACQUISITIONS. The museum has recently added three exceptional minerals to its collections. All are among the best of their kind. An extraordinary orthoclase feldspar crystal from Madagascar was purchased in December 1989. This very well-formed crystal is deep yellow and completely transparent. An epidote specimen from Namibia was donated in January by Mr. and Mrs. Hyman Savinar. The specimen, consisting of lustrous dark green crystals, may be the finest ever found in Africa. Last, but certainly not least, is a specimen of realgar from China. The large realgar crystals are a vivid bright red with lustrous faces and exquisite form. The realgar crystals are aesthetically intermingled with large transparent calcite crystals, yielding a specimen of almost unbelievable beauty. Plans for the exhibition of these specimens have not been finalized.

TO THE BRINK AND BACK

The Battle to Save the California Condor

by LLOYD KIFF

We sat on the tailgate of our pickup truck parked on the side of Hopper Mountain on a cold, clear February morning in 1985, studying a nearby ridgetop, where a flock of ravens worked busily over the carcass of a black-and-white calf. A Golden Eagle soared swiftly by us downslope, its metallic yellowish head and dark plumage indicating adulthood. More ravens appeared overhead, croaking excitedly. Suddenly, a great dark shape loomed over the ridgeline and passed low over the carcass, scattering ravens in its wake. It headed directly toward us. Reaching our observation point, the condor circled overhead several times in ever-tighter, ever-lower circles. I clicked away frantically with my camera, whirling so quickly as I attempted to follow the bird that I nearly fell from dizziness. The condor soared so closely that we could look right into its reddish eye and easily make out the number 9 on its two prominent wing markers. Satisfied with its inspection of us, the huge bird soared back to the carcass on the ridgetop, landed with a bounce, and began to feed on the calf.

We had no way of knowing that this very California Condor was destined for immortality. When AC-9 (for Adult Condor #9) was captured two years later, he was the last of his species known to exist in the wild, and he joined twenty-six other condors already held in captivity at the Los Angeles Zoo and the San Diego Wild Animal Park. They represent the last hope to save this magnificent species.

Historical Perspective

Condors have always commanded attention because of their great size and the air of primal mystery that surrounds them. A soaring condor at close range stirs the dullest soul, even one ordinarily indifferent to natural things. Furthermore, for generations of Americans, the California Condor has been synonymous with rarity. Exactly one hundred years ago the pioneer California ornithologist, James Cooper, wrote, "there can be little doubt that unless protected our great vulture is doomed to rapid extinction."

Up until the late Pleistocene epoch the California Condor apparently occurred throughout much of North America, from northern Mexico to southern Canada east across the southern United States to Florida, where no fewer than twelve different fossil sites have yielded condor remains. About five years ago, a surprising find of three 11,000-year old condor bones was made in upstate New York, where the species evidently lived in spruce-jack pine woodland, a boreal (northern coniferous) habitat. A period of major decline of the condor occurred throughout much of its range in North America around ten-thousand years ago, coinciding with the extinction of many of the large Pleistocene mammals, including giant sloths, mastodons, camels, and saber-toothed cats.

By the time Europeans arrived in North America, the condor was confined to the Pacific coast region from northern Baja California to southern British Columbia. It is probable that the species has not occurred east of this region within modern times, although some authorities accept a handful of nineteenth-century reports of condors from Arizona. Over the last two centuries, the condor population suffered a drastic decline, culminating with the capture of AC-9 in 1987.

It is worth emphasizing that the California Condor experienced major declines during two completely separate periods for completely unrelated reasons. Its disappearance from most of North America at the end of the Pleistocene probably resulted from the extinction of its principal food sources, large mammals. Yet condors persisted along the Pacific coast, having survived the bottleneck of Pleistocene extinction, unlike several other large scavenging bird species. The subsequent, more rapid decline that occurred throughout this refugium was not associated with major environmental changes, as was the first, and it was by no means evolutionarily inevitable. In fact, there is little reason to suppose that condors would have vanished from the Pacific coast, if humans had not come on the scene. For all we know now, the California Condor population was stable, or even increasing, in the early nineteenth century, when Lewis and Clark encountered the birds feeding on beached salmon along the Columbia River.

Failure to distinguish between the two periods of condor decline and their different causes has led many writers to erroneously assert that the species is a Pleistocene relic already doomed to extinction, or, in the words of avian paleontologist Loye Miller "a species with one foot and even one wing in the grave." Yet the same judgment would not be weighed against the related

Opposite page: Condor captive breeding programs at the San Diego Wild Animal Park and the Los Angeles Zoo represent the last hope to save this magnificent species.

ALLISON LEETE

JESSE GRANTHAM

IC-1 was found dead at Blue Ridge in March 1984. The young male condor had died a slow death from lead poisoning; it had ingested fragments of spent bullet from a carcass that it had eaten.

WRITERS HAVE ERRONEOUSLY ASSERTED THAT THE CONDOR WAS A "SPECIES WITH ONE FOOT AND EVEN ONE WING IN THE GRAVE" EVEN BEFORE CALIFORNIA WAS SETTLED BY EUROPEANS.

Andean Condor, which has a lifestyle similar to that of the California Condor. Indeed, the record shows that the California Condor is a fairly adaptable species in choice of food and habitat. Its principal failing seems to be that it did not have the good fortune to evolve bullet-proof vests or the capacity to nest on building ledges like pigeons.

Causes of Decline

One of the most frustrating aspects of the whole condor recovery program is that although biologists agree that the reason for the near extinction of the species is the unnaturally high rate of mortality of free-flying birds, the relative importance of the principal sources of such losses is still unclear.

Over the years, shooting has generally been regarded as the single most serious cause of the decrease in condors, and most early accounts of the species mention birds that were shot. In condemning the common practice of shooting condors out of curiosity, William Leon Dawson wrote bitterly in 1923 that "a dead Condor could win a moral beggar a momentary applause at the local hardware store; but a Condor wantonly slain was a dead epic, a treasure-laden galleon '*spurlos versenkt*,' and an indictment of a civilization false to its core." Shooting losses tended to be better documented than other causes of mortality, and those on record (nearly two hundred) no doubt represent a fraction of such incidents.

Although the incidence of condor shooting probably declined in recent years in response to stronger laws and more publicity about the plight of the bird, it was distressing to find as late as 1986 that a captured condor carried several shotgun pellets in its body. When the bird died not long afterward, the cause of the bird's death was not the lead shot, however, but rather the fragments of a spent bullet it had swallowed, which guaranteed it a slow death from lead poisoning. In the early 1980s condor biologist Noel Snyder was the first to suggest that lead poisoning might have been a major factor in the decline of the condor and other scavengers, who unknowingly ingest bullet fragments as a part of their carrion diet. As if on cue, individual condors were found in 1984, 1985, and early 1986 dying or already dead from this insidious cause. Although exposure probably occurred during the hunting season and therefore most likely involved deer carcasses, there is a great deal of shooting of other nongame animals, especially coyotes, throughout most of the condor's recent historical range. This, too, could represent a serious problem for the birds.

The role of lead poisoning in the historical decline of the California Condor is not known, but it was very likely quite important. Characteristically, birds suffering from lead poisoning survive for weeks or even months after the original ingestion of lead; thus, they tend to die in remote localities well away from the source of the poisoning. In the premanagement condor era, there was little likelihood of a dead condor being analyzed for contaminants.

Many writers have alluded to losses of condors from other poisons, especially strychnine and 1080, a rodenticide, but there still is not convincing documentation of specific incidents. Because

LLOYD KIFF

Condor habitat without condors—a trail into the Upper Sespe Creek near Topatopa Bluffs. The huge vultures may soon be released into their old domains.

deaths of other large vulture species from strychnine poisoning is still known to occur on other continents, it seems likely that the formerly common practice of setting out strychnine-laced bait for range predators could have indirectly accounted for the loss of many condors.

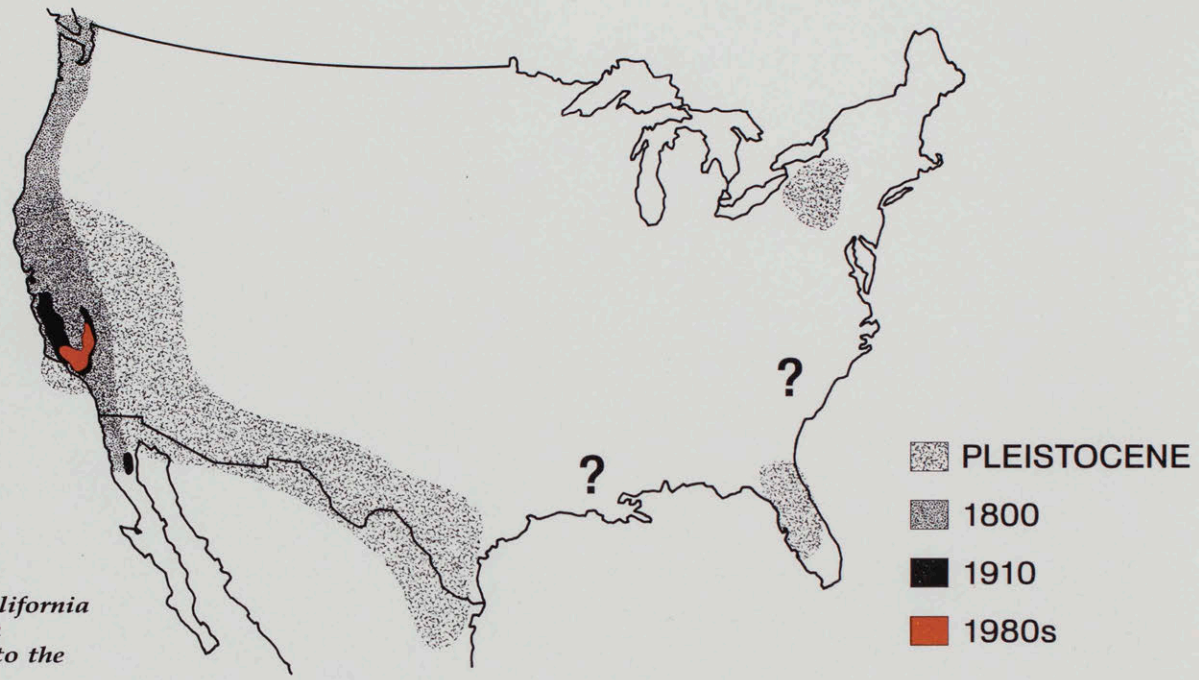
The potential impact of modern synthetic chemicals has also been of considerable concern. During the heyday of DDT use after its introduction in 1947, one pound per acre per year was applied to over 190,000 acres of prime condor foraging range in the southern San Joaquin Valley for at least fifteen years. Eggshell thickness of the condor declined nearly 30 percent during the 1960s, and there were a number of cases of eggs apparently broken in nests. It is well known that DDE, a breakdown metabolite of DDT, causes such eggshell thinning in many species of birds. However, more recent studies on condor eggs have revealed a strong correlation of eggshell thickness with egg size in this species, so it is now impossible to determine how much of the apparent shell thinning in the 1960s was due to possibly smaller eggs and how much might have been due to DDE effects. Furthermore, although data on condor breeding success from the 1960s are fragmentary, it is known that at least some young were successfully produced during the period.

DDT was banned for domestic use in 1972. Thereafter, most condors laid eggs of normal thickness, although two eggs laid in 1986 by the last breeding female in the wild, coincidentally the mate of AC-9, were inexplicably thin-shelled and heavily contaminated with DDE. The first-laid egg was particularly fragile, and it was crushed by the incubating female soon after it was laid. The other egg was removed from the nest by researchers and taken to the San Diego Wild Animal Park, where it was hatched successfully, despite being even more heavily contaminated with DDE.

Various incidental causes of condor mortality include the capture of birds for pets or display in zoos, egg collecting, and collisions with powerlines or other obstacles. One bird had the misfortune of drowning in a cattle water trough, while another was poisoned by a cyanide device set out by a governmental agency to kill coyotes. Through all of this, virtually the only natural deaths of condors on record are those of two birds that died in a hailstorm in the Cuyama Valley in 1936. Even the only documented "natural" form of condor egg loss, predation by ravens, may be man-related, given the phenomenal increase of the latter species in recent decades as a result of the proliferation of open garbage dumps and road kills.

The Management Era

The net result of all of these factors was the unrelenting decline of the condor from the time of Lewis and Clark to the 1987 capture of AC-9. In 1977, two national organizations, the American Ornithologists Union and the National Audubon Society, convened an interdisciplinary panel of prominent biologists to consider the plight of the bird. In their 1978 report, the group recommended the immediate implementation of an intensive condor management program, incor-



Range of California Condor from Pleistocene to the 1980s.

porating such techniques as radiotelemetry (radio tracking of the birds) and possibly captive breeding. The former technique would assist researchers to monitor the movements of the wild birds carefully to delineate critical condor habitat, whereas the latter approach would lead to increased reproduction (up to six times the usual rate of one chick every two years) in an atmosphere of minimal mortality.

To implement the new recovery program the Condor Research Center was established in Ventura by the U.S. Fish and Wildlife Service and the National Audubon Society in 1980. The intent of this initially promising union was to protect the wild birds and their habitat while learning more about them and the causes of their mortality. It soon became obvious that a vigorous captive breeding program would indeed be necessary to save the species, but bureaucratic timidity delayed its initiation until late 1982. From that year until 1986 the nucleus of a captive flock was built up primarily through a technique called *multiple clutching*. Condors lay only a single egg per nesting attempt, but when that egg is lost or removed, they will often replace it within another. Following the direct documentation of this behavior in wild condors, researchers were allowed to take first and, sometimes, second eggs for hatching at the San Diego Zoo. The birds were allowed to hatch replacement eggs to maintain the wild population. In addition, several nestling condors were taken from the wild to the Los Angeles Zoo, and a few nonbreeding adult birds were also captured.

Throughout the early 1980s it was the hope of participants in the program that some condors could be maintained in the wild right up to the time of the planned release of captive birds and that the wild flock would serve as guides for the newcomers. For several years, success appeared likely, if not guaranteed. There were at least four breeding pairs of wild condors in 1981, 1982, and 1983 and five in 1984. Then the bottom dropped out—nine out of the remaining fifteen birds in the wild vanished mysteriously between November 1984 and April 1985. Where we had hoped to have at least five breeding pairs in the spring of 1985, we had but one. Only one of the missing birds, a victim of lead poisoning, was recovered for a necropsy. Another of the lost condors had been tagged and equipped with radio transmitters, one on each wing, but neither the bird nor its transmitters were ever found. Given the various constituencies who would be happier in a world without condors, it was difficult not to suspect human intervention.

By the end of 1985, both the California Fish and Game Commission and the U.S. Fish and Wildlife Service recognized the desperation of the situation, and the decision was made in mid-December to bring all of the remaining wild condors into captivity. This recommendation was supported by virtually every biologist involved in the recovery program, but near consensus made it no less traumatic.

Before the decision could be implemented, however, the National Audubon Society filed suit on procedural grounds to obtain an injunction against trapping the birds, arguing that even with a successful captive breeding program, criti-

SAVING THE CALIFORNIA CONDOR

Three Questions People Ask Most Often

DONALD L. BLEITZ

Why release birds into the same areas where they were driven to extinction? What has changed?

We are hopeful that attitudes toward condors are changing as a result of publicity and education and that shooting of the birds will occur rarely, if at all. The results of the Andean Condor experiment are encouraging in this regard, since none has been shot so far. Furthermore, in all cases, we will be releasing condors in areas with minimal shooting, although we cannot be sure that they will remain in such refugia indefinitely. Since DDT has not been used legally since 1972 in California, we expect it to continue to be a diminishing problem for condors, despite the unexpectedly thin eggs laid by the female AC-8 in 1986. The lead bullet problem is a vexing one. Some exciting research is underway on potential replacement materials for lead bullets, and phasing out this type of ammunition in the future is possible. Attempting to restrict shooting throughout the potential range of the condor is not practical and might even result in a backlash against the birds. The only defense against this cause of mortality at the present time is to provide released condors with uncontaminated food. Finally, we have the capacity to breed condors up to six times faster in captivity than in the wild. Perhaps we can simply swamp out the mortality factors.

Will birds ever be self-sufficient?

Probably not, at least in the foreseeable future. It is likely that released birds may soon reach the point where they will survive in the wild and reproduce successfully, perhaps even to the point of being numerically self-sustaining. However, we will probably be forced to feed them supplementally indefinitely, especially in areas outside of California. Actually, the California condor has been dependent upon man for food for at least two hundred years, since its principal food within historical times has been cattle. Many biologists have suggested that the species may have actually increased in numbers in central California during the great land grant period in the first half of the nineteenth century when native ungulates were displaced by thousands upon thousands of cattle and sheep. There is little functional difference between encouraging ranchers to leave dead cattle on their range and placing them there for condors deliberately. Ideally, native ungulate populations may be reestablished on the Carrizo Plains and in other future condor release areas to serve as a more natural food source.

Why spend so much money on the condor program relative to other endangered species programs?

The condor program has frequently been called the flagship of federal endangered species programs. Like the United States space program, it generates a multitude of side benefits, including the development of new techniques for captive breeding, releases, and genetic analyses, as well as land preservation. Nearly a quarter of a million acres of habitat are presently being protected as a result of the condor program. In fact, most of the total expenditures attributed to the condor program can be specifically traced to land acquisition. Whether or not we save the condor, we will still have the land for its basic ecological values.

Including substantial contributions from the private sector, estimates of the amount of money spent on the condor program over the past fifteen years range from $20 to $25 million. Even so, the condor program is not necessarily the most expensive of the endangered species programs, as probably more has been spent on saving the Bald Eagle, Peregrine Falcon, and now the Northern Spotted Owl. Furthermore, on an international or even national scale the amount of money spent on condors is comparatively negligible. We live in an affluent society where individual athletes have long-term contracts larger than this figure, individual rock stars and actors make greater sums in a year, and individual paintings sell for more at auction. Is not the condor worth an equivalent amount as an art form or for its entertainment value? In aggregate, the budget for the entire endangered species program since its inception would not be sufficient to pay for the construction of a single modern bomber. Is not a complete arsenal of the world's biotic diversity a better defense for our future than airplanes?

THERE MAY BE AS MANY AS 14 FAMILY LINES REPRESENTED IN THE PRESENT CAPTIVE CONDOR FLOCK.

cal habitat needed for eventual releases would be lost if all of the condors were removed from the wild. In addition, Audubon insisted that a few birds must be left in the wild to serve as guides to nest sites, roosts, and foraging areas for captive-produced birds to be released later. Proponents of the trapping plan pointed out that these arguments were moot, since there seemed to be little possibility that the three remaining birds could survive long. Furthermore, a number of condor biologists felt that the existing condor culture was a proven failure. They argued that the behavioral traditions of the existing population had led to near-extinction of the species, and they suggested that it would be wiser simply to begin anew and release naive birds into a safer and more controllable area. Perhaps they recognized that it might be easier to change the traditions of the condors than the behavior of people.

The Audubon Society's suit wore on acrimoniously for several months before a ruling was made in late spring 1986 in favor of the trapping plan. By this time, most of the society's own biologists concurred that trapping the remaining birds was the soundest strategy. Audubon also lobbied heavily for federal acquisition of Hudson Ranch, a 13,000-acre property in the southern San Joaquin Valley, where much condor foraging activity had occurred in recent years.

Discussions during this period led to the formation of a new Condor Recovery Team. A former incarnation of the team, an advisory body appointed by the regional director of the U.S. Fish and Wildlife Service, had been generally supportive of the proposed trapping plan, but was not allowed to meet after August 1985. The Condor Recovery Team, like the equivalent groups for other endangered species, is responsible for formulating an interagency recovery plan and recommending strategies for saving the condor. Each of the cooperating agencies involved in the condor recovery program submitted nominations for the new team. The U.S. Fish and Wildlife Service settled on the makeup of the new group during the summer of 1986, and the first meeting was held in August.

The first recommendation of the new team was to reaffirm that all of the remaining California Condors should be captured immediately. At the same time the team recommended the acquisition of Hudson Ranch, purportedly the object of Audubon's defection all along. By this time, only three condors, all males, were left in the wild. They included AC-9, AC-2, who was the male of the so-called Santa Barbara pair (his mate was lost to lead poisoning in January 1986), and AC-5, the "Sequoia bird," so named because he and his mate (also missing) had nested in a giant sequoia tree in the Sierra Nevada in 1984. Trapping the birds took longer than anticipated because of weather and logistical problems and still more behind-the-scenes footdragging by opponents of the capture plan. It was not until April 19, 1987, that AC-9 was netted by condor biologist Pete Bloom on the newly established Bitter Creek National Wildlife Refuge, formerly the Hudson Ranch. In a national radio interview following the capture, Bloom described his feelings of profound sadness as he "folded the wings of the last condor."

Captive Breeding

At its second meeting in October 1986, the Condor Recovery Team settled on several conditions to be met before releases of condors to the wild could be undertaken. Specifically, at least 96 percent of the genetic material of the founders from which the release birds have descended must still be represented in permanent captivity. (This provision was suggested by Michael Soulé, a leading population geneticist and team member, and translates to retaining at least five offspring from each of the pairs contributing to releases.) In addition, the team recommended that there should be at least three captive-produced birds physically and behaviorally suitable for release and that at least three pairs of condors should be successfully reproducing. Finally, the team recommended that all of the birds then in captivity should be retained as breeding stock for the rest of their lives, although recognizing that this position might be changed in the future, depending upon unforeseen events.

All of these conditions were cast bravely upon the waters before California Condors had even reproduced successfully in captivity. However, few biologists ever doubted that they would breed readily under captive conditions, since the closely related Andean Condor has long been known as one of the most dependable breeders in any large zoo collection. That species first bred successfully in captivity in the London Zoo in the 1840s and has reproduced in zoos on every continent by now, including the Los Angeles and San Diego zoos. Some birds have even produced four

Courtesy RAYMOND QUIGLEY

Two children pose by a mounted condor in a photograph taken in 1917. The condor was shot for sport. Over the years, shooting has generally been regarded as the single most serious cause of the decrease in condors.

young in a single breeding season.

By the spring of 1988, the confidence of the recovery team was rewarded. A single condor chick, Molloko, was hatched at the San Diego Wild Animal Park on April 29, 1988, representing a giant step on the road to condor recovery. Another four condor chicks, Mandan, Shasta, Tawasinah, and Kaduku, representing parents from both zoo populations, were produced in 1989. Thus, the total California Condor population now consists of 40 individuals, about equally distributed between the San Diego Wild Animal Park in Escondido and the Los Angeles Zoo. Fortuitously, the sex ratio is also even.

Three of the 1990 eggs were laid in January, an unprecedented early beginning to a condor breeding season. Another unanticipated, albeit welcome, development is the tendency for birds younger than the presumed requisite age of six years to attempt breeding. Eggs produced by such "adolescents" are typically infertile, but their precocious interest in breeding bodes well for the future. Nine pairs of captive condors produced an egg in the 1990 breeding season, and there are one or two additional pairs that could potentially breed successfully next year. It now appears probable, although not certain, that the first releases of California Condors to the wild may be undertaken in 1991.

There has been perennial concern over the possible effects of inbreeding in the condor population, and anxiety has intensified as the number of condors dwindled ever smaller. Consequently, genetic considerations have been taken into account in a computer model created by Michael Gilpin of the University of California at San Diego. The model incorporates data on sex, age, and genetic relatedness to predict the most favorable pairings. It permits population geneticists to calculate such predictors of success as inbreeding coefficients, gene drops, and founder contributions in the captive population for hypothetical matings.

DNA fingerprinting research conducted by Oliver Ryder of the San Diego Zoo has been a useful supplementary source of information on the relatedness of the captive flock. By comparing their DNA characteristics with those of condors of known parentage, it is possible to make predictions about the relatedness of condors whose specific histories are unknown, thus minimizing the possibility of inbreeding. Relying on preserved blood samples from both living and recently dead condors, Ryder has confirmed that there may be as many as fourteen family lines represented in the present captive flock. This has considerable bearing on how the birds are paired, since ideally each of the family lines should be equally represented in the population. There are plans to extract samples of DNA-bearing tissue from museum condor specimens to obtain a measure of the extent of genetic variability in the overall condor population over the last two centuries.

ALLISON LEETE

An adult condor stretches its huge wings in the sun at the San Diego Wild Animal Park. Condors have proved remarkably adaptable in captivity.

The Condor Recovery Team, which has responsibility to recommend pairings, also relies on behavioral data meticulously gathered by zoo personnel. At this point, there is little need to attempt to pair birds that seem to be incompatible. Some condors may require several years together before forming a pair bond, however, so it is often difficult to decide just when to switch to different pairing configurations. Fortunately, the recovery team has seldom been forced to make choices between the best pairings from a genetic standpoint and the easiest breeding possibilities based on the affiliation between particular individuals. Eventually, in the case of reluctant suitors, it may be necessary to use artificial insemination techniques to ensure the preservation of certain family lines, and some preliminary research on developing this technique for condors has been initiated.

To help ensure against the loss of a large proportion of the species from a virus, fire, earthquake, or other disaster and also to house the number of condors thought to be necessary to maintain an adequate breeding population, the recovery team recently recommended that a third major captive breeding facility should be established. The selection of such a facility is currently underway. Condors are remarkably adaptable in captivity, and there is no evidence suggesting that close contact with humans might hinder them from breeding successfully, even though it would probably make the birds unsuitable for release. Therefore, if things go as planned, it should eventually be possible to place individual pairs of breeding condors around the country in many zoos with the offspring being contributed to several wild populations.

Habitat

Over the past three decades, the popular press has characterized the controversy surrounding the condor recovery program as an inevitable conflict between those who would manage wildlife, including the condor, and those who favor a hands-off policy. This argument has been waged more in the media than in the back rooms of government policy makers. Wildlife agencies, by their very nature, are compelled to manage, and they will continue to manage the condor. Besides, the great majority of condor interests agree that temporarily reducing the condor to a mere creature of captivity is still better than having a dignified but dead condor.

A more important dichotomy of condor attitudes exists between those who regard the species as being habitat-limited and those who feel that the principal limiting factors have been various forms of direct mortality caused by man. Most biologists, including the Condor Recovery Team, fall into the latter group, whereas the former includes such environmental organizations as the Friends of the Earth, Sierra Club, and, in recent years, the National Audubon Society. These groups have portrayed the condor as the very symbol of a species nearly extirpated by loss of habitat, and they have not hesitated to use the condor as a device to combat specific land use projects. Nevertheless, they have shared an honest concern over the proven causes of condor mortality with those less concerned about habitat matters in the short term.

Although condor biologists agree that a lack of space will eventually be a problem for all living creatures, they are quick to point out that the condor is an unusually habitat-independent species. AC-9, the last condor, ranged over five or six million acres of central California, of which two million are already under federal protection from development. All known condor nest sites and most important roost sites used within the last eighty to ninety years are on national forest lands, and recent acquisitions have added large blocks of potential condor foraging habitat to federal and state holdings. Clearly, land use trends must be monitored carefully, but dwelling at this point on habitat matters to the exclusion of finding solutions to mortality from other causes, or promoting a strong captive breeding program, is equivalent to treating a severely hemorrhaging patient for a chronic cough.

Many predicted that a wholesale onslaught on condor habitat would follow the capture of the last wild condor, but this fortunately has not happened. The U.S. Forest Service and other land-use agencies have held the line, and closures originally established to protect condors have been maintained. For example, a proposed energy-generating wind farm in the rolling hills near Gorman was recently denied in large part because of the danger it might pose to condors that will eventually soar there. It is not certain how long the recovery program can continue to use this "power of attorney" in the absence of its feathered client, and the sooner that releases can begin, the better.

ONE WRITER LIKENED RELEASING ANDEAN CONDORS IN CALIFORNIA TO THE SPRING TRAINING SESSIONS THAT PRECEDE EACH BASEBALL SEASON.

Release Strategies

Many critics of the program have contended that it may be possible to breed condors readily in captivity, but that reestablishing them in the wild will be a different matter. Without question, this will be the most difficult part of the process, but we are confident that it can succeed. It may be possible to begin releases of California Condors to the wild as early as 1991.

To hedge our bets, we are conducting an exciting experiment originally conceived and designed by Noel Snyder and zoo biologists Cathleen Cox, Art Risser, and Mike Wallace. Specifically, release strategies and techniques are being tested and a release team is being trained by using the similar Andean Condors as a surrogate. Nature writer Sandy Wohlgemuth likened the experiment to the spring training sessions that precede each baseball season. Wallace has conducted similar experiments with captive-bred Andean Condors in Peru, where he was successful in reintroducing at least seven captive-bred birds to the wild.

A TANTALIZING NOTION THAT HAS SURFACED REPEATEDLY IS TO RELEASE CALIFORNIA CONDORS IN THE GRAND CANYON AREA.

The Andean Condor release experiment was initiated by the U.S. Fish and Wildlife Service and the Los Angeles Zoo in fall 1988 and is expected to continue through at least the fall of 1990. Seven birds, including one group of four and another of three, were released in 1988. Two additional groups of three birds each were released separately in early 1990.

Andean Condors are by no means abundant in their native South America, but they are relatively common in North American zoos. The birds being used in the experiment were produced specifically for the project by cooperating zoos around the United States. The zoos ordinarily do not take advantage of this species' willingness to breed readily in captivity, since the offspring require a large amount of space and food.

Andean Condor eggs were gathered from the participating zoos and hatched at the Los Angeles and San Diego zoos. When the chicks were three months old, they were transported to the release sites in the Sespe area. One chick died en route to the release area, apparently the victim of stress. The others were placed in release structures consisting of simulated caves and large adjacent net-covered areas, where they remained for nearly four months, as they matured, socialized, and acclimated to the area. During this period, their behavior was observed closely by researchers through video monitors and one-way glass, and they were fed surreptitiously so as to minimize their acclimatization to humans. After about four months the netting was removed from the enclose, and the birds were allowed to fly when they felt so inclined.

The experiment has proven to be a success so far. Four of the original birds are still in the field, and they have performed well, offering much encouragement for the eventual releases of California Condors. They learned to soar without any human encouragement. They appear regularly at the established feeding stations, and they have remained dependent upon the contaminant-free food put out for them, despite wandering great distances from the Sespe area. Losses have been surprisingly few. One bird died when it collided with a powerline, one simply never developed normally, either physically or behaviorally, and was taken back into captivity, and another displayed a tendency to be too tame for her own good. She, too, was eventually taken back into captivity so as not to be a bad influence on the other birds.

Acclimatization to humans is the main concern in the experiment, since they inevitably represent the chief threat to the birds. The initial release site was chosen in part for the many challenges it presented, especially in terms of its proximity to frequent human activity associated with local oil-drilling operations. In fact, the site did not work as well as hoped, and researchers suspected that this led to the first birds released in 1988 showing less fear of humans than desirable. Thus, the 1990 releases were made from more remote sites, and the birds originally released were brought back into captivity. It will be interesting to see if the birds released later tend to distance themselves more from human activities.

Only female Andean Condors were released in the experiment, partly to allay fears that this exotic species might elude capture and eventually become established as a breeding species in California and also because female Andean Condors are more similar in size to California Condors than are the larger males. Thanks to an inspiration by Mike Wallace, five male Andean Condors produced as a by-blow of the project were released in Colombia as a part of a program to bolster the depleted native population of that species. The project, which is continuing in 1990, is being administered by Colombian agencies in cooperation with eight North American zoos and the U.S. Fish and Wildlife Service. When the female Andean Condors now soaring over southern California are recaptured, they, too, will be

MICHAEL WALLACE

transported to Colombia to join the males already released there.

There is general agreement among all condor program participants that the first releases of California Condors should occur in the Sespe Condor Sanctuary, the heart of the recent historical nesting range of the species. This area is relatively free of most known condor mortality factors, especially shooting (and thus lead poisoning), it contains numerous proven nest sites, and it is virtually devoid of human intrusion. As the behavior of the experimental Andean Condors has shown, we do not expect that the condors will remain in the Sespe region indefinitely, but they may continue to feed there. The Andean Condors have routinely wandered south into the San Gabriel and San Bernardino Mountains and north to Santa Barbara County before returning home to the Sespe for food at their established feeding stations.

We expect eventually to release condors in other parts of California. A very promising strategy would take advantage of The Nature Conservancy's newly acquired 180,000-acre Carrizo Plain preserve in Kern County. Linked with historical nesting areas in the nearby Sisquoc region and Coast Ranges and stocked with native antelope and tule elk, the Carrizo could serve as a major condor foraging area. Furthermore, portions of the Coast Ranges in San Luis Obispo and Monterey counties also contain much suitable condor habitat, and the species occurred there commonly until at least the early 1970s.

Several prominent biologists, including Tom Cade and Hartmut Walter, have suggested that it would be a good idea to release condors on Santa Cruz Island, now mostly owned by The Nature Conservancy. A potential drawback of such a plan is the continuing high levels of contaminants, especially DDE, around the California Channel Islands. Although the only evidence of condor occurrence on the Channel Islands is a single prehistoric condor bone found on nearby Santa Rosa Island, it is possible that the species once occurred on the islands regularly, just as Andean Condors still soar to the "guano islands" off the coast of Peru in search of marine supplements to their diets. There is no question that the California species must have foraged regularly on the mainland coast, as the type specimen was collected in December 1792 while it fed on a beached whale in the company of grizzly bears at the present-day location of the town of Monterey.

Female Andean Condors have been released as surrogates in the California Condors' former range to study the problems of releasing captive-bred birds in the wild. The closely monitored birds, which were introduced to the Sespe area as chicks, have learned to soar without human encouragement and have regularly appeared at established feeding stations.

Despite the insistence of its proponents that Bitter Creek National Wildlife Refuge be a prime release site, there has never been any serious consideration of it for that purpose. At the present time the high level of uncontrolled shooting in the southern San Joaquin Valley simply makes this too dangerous an area for condors. It is expected, however, that condors will eventually move back into the foothills of the San Joaquin as they expand outward from the mountainous release areas. Within the foreseeable future, release sites will be in areas where condors would fledge naturally. Thus, ironically, the only function of Hudson Ranch to the condor recovery effort since its acquisition to date has been to serve as the site of the capture of the last condor.

An important task of each recovery team is to set recovery objectives. The preliminary thinking by the team on this matter is that "downlisting"

CLARK SUMIDA

This egg, laid by the last breeding female condor in the wild, was inexplicably thin-shelled and loaded with DDE. It was crushed by the incubating female soon after it was laid.

or "delisting" of the condor from the endangered species list should not be considered until there are at least three disjunct populations of condors, each with at least one hundred birds. In this case, such populations would probably include a captive population, another in the recent historical range in California, and a population outside of California.

In this connection, a tantalizing notion that has surfaced repeatedly over the years is to release condors in the Grand Canyon area. Judging from the exciting findings of Steve Emslie, who found condor remains in cave after cave in the Grand Canyon, the species was a common resident there during the late Pleistocene. The lack of later records suggests that the species disappeared from the region because of a lack of food. Although food supplies may still be thin for condors in the Grand Canyon area, there is an abundance of potential nest sites, water, and unrestricted airspace. In addition, hunting and shooting practices are carefully monitored by local Indian tribes and government agencies, and it would be a relatively simple matter to supply the birds with an adequate food supply.

Another potential condor release site may be the huge Gray Ranch, a property comprising over 321,000 acres in the Animas Mountains of southwestern New Mexico. The ranch was acquired in January 1990 by The Nature Conservancy. There is talk of creating a Serengeti-like ecosystem there by combining the ranch holdings with an even larger contiguous tract in adjacent old Mexico. To be attractive for condor releases, hunting and shooting on the ranch would have to be prohibited, or at least tightly regulated.

Final Observations

In a sense, the condor is a metaphor for California. Like the land itself, the condor has enjoyed periods of exceptional prosperity only to suffer grievous losses from human overpopulation, overdevelopment, and unwise agricultural practices. Like modern California, its salvation now rests upon technological solutions. The condor going back into the wild will be the offspring of environmental tinkering, but it will be no less a condor for such an origin. Present-day purists may reject the released birds as not being "real condors," but future generations will not. Perhaps we can even look ahead to a time when condor watchers will not even remember this desperate period, when we and the condors stared extinction in the face and stepped back from it.

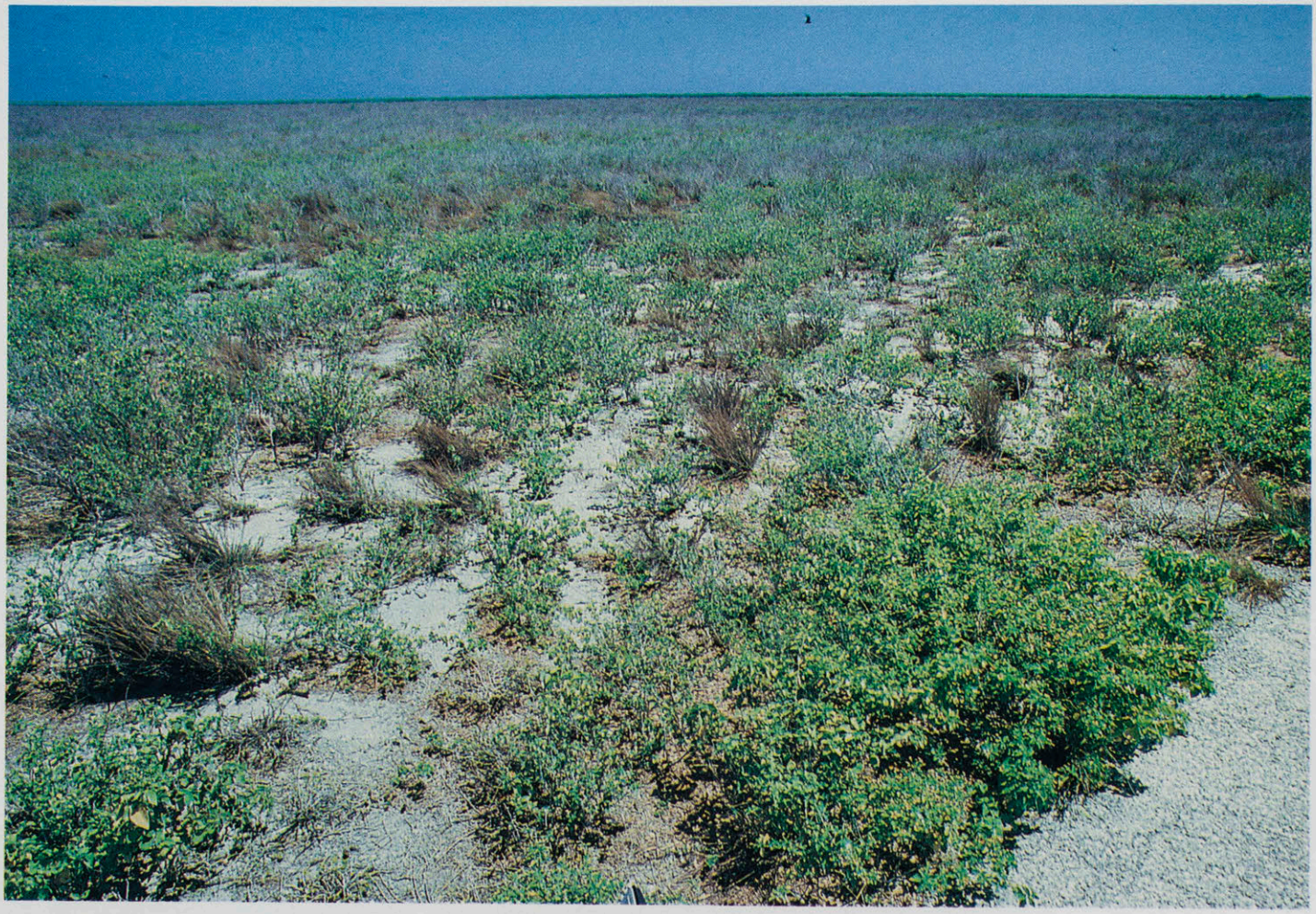
Lloyd Kiff is Curator of Ornithology at the Natural History Museum and Leader of the Condor Recovery Team.

Can Birds Forecast the Weather?

Central Pacific Seabirds May Provide Early Warning for El Niño Events

by ELIZABETH ANNE SCHREIBER

Photographs by Ralph W. Schreiber and Elizabeth Anne Schreiber



Previous Page: A Great Frigatebird chick begs for food on Christmas Island in 1984. The bones of the previous year's chick lie below. A change in weather patterns caused by the 1982–83 El Nino-Southern Oscillation (ENSO) depressed nutrient-rich waters that normally provide abundant feeding areas for seabirds. As a result, 80 to 90 percent of the birds from Christmas Island died.

In 1979, my husband Ralph Schreiber and I began studying the breeding biology and ecology of tropical seabirds of the central Pacific. The coral atolls in this region are nesting grounds for millions of birds, including boobies, frigatebirds, tropicbirds, petrels, shearwaters, and terns. Very little was known about most of these species because of the remoteness of the islands on which they nest–no one knew how long the birds live, if they mate for life, or how many young they raise in a lifetime. We set out to find answers to these questions, concentrating on members of the Order Pelecaniformes–the boobies, frigatebirds, and tropicbirds. We worked primarily on two islands just north of the equator: Christmas Island (2 degrees north latitude, 157 degrees west longitude) and Johnston Atoll (16 degrees north latitide, 169 degrees west longitude).

We began to discover some fascinating facts about the lives of these birds. For example, they live for 25 to 35 years, and most pairs do mate for life. The birds return to the same nest site each year, and they generally stay with the same mate if they have been successful at raising a chick together.

The Mystery of the Birds That Disappeared

Then, suddenly, in fall 1982, nearly all the birds disappeared from Christmas Island. Millions of them—just gone. A few young frigatebirds were still alive when we arrived in November, but their parents were not around to feed them. We watched helplessly as they starved to death, unable to fly away themselves. The island itself, normally a desert-like atoll, was flooded from heavy rains that continued for months.

We had come to work, expecting to handle hundreds of birds and to mark nest sites, weigh and measure chicks to monitor their growth, and band adults. Not

Christmas Island's climate is usually arid (left). During an ENSO, however, rain falls heavily, resulting in the lush growth seen at right. The difference in the two photographs vividly depicts the effects of the changing weather conditions.

knowing what was going on, we felt we had wasted a trip because there were no birds and no work for us to do. We had no idea of the worldwide impact of what was going on.

We knew of no explanation for the birds' absence this year. On our way home, we stopped in Honolulu to talk with Dr. Klaus Wyrtki, an oceanographer at the University of Hawaii. He was fascinated by our report on the lack of birds on Christmas Island, and he had an explanation: there was an El Nino-Southern Oscillation (called ENSO for short) underway. This oceanographic and atmospheric anomaly occurs periodically every two to ten years and primarily affects the coasts of Ecuador and Peru. But the ENSO in progress would eventually be estimated to be the most severe one in five hundred years, affecting climates–and birds–around the world.

An ENSO occurs in response to a change in high and low pressure zones in the Pacific Ocean. No one knows why the change occurs, but it causes the normal easterly wind across the central Pacific to reverse 180 degrees and become westerly. This in turn pushes the warm western Pacific waters back toward the east, depressing the nutrient-rich, cool waters that upwell through the central Pacific and along the coasts of Peru and Ecuador. These two areas provide an abundant food supply for millions of seabirds in non-ENSO years. The upwelled nutrients feed tremendous fish populations that in turn feed the seabirds.

When the upwelling ceases, the fish disappear and the birds either must find food elsewhere or die of starvation. Most of the birds that should have been nesting on Christmas Island in fall 1982 never returned to the island. We do not believe they nested on another island because all these species are known to return to this natal colony to nest. This means that 80 to

An adult Masked Booby with a six-week-old chick. Nesting failures by these birds in 1985 and 1989 signaled the onset of ENSO conditions. Determining how the birds sense changes in weather patterns may help humans prepare for droughts and flooding caused by an ENSO.

90 percent of the birds from Christmas Island died as a result of the 1982-83 ENSO.

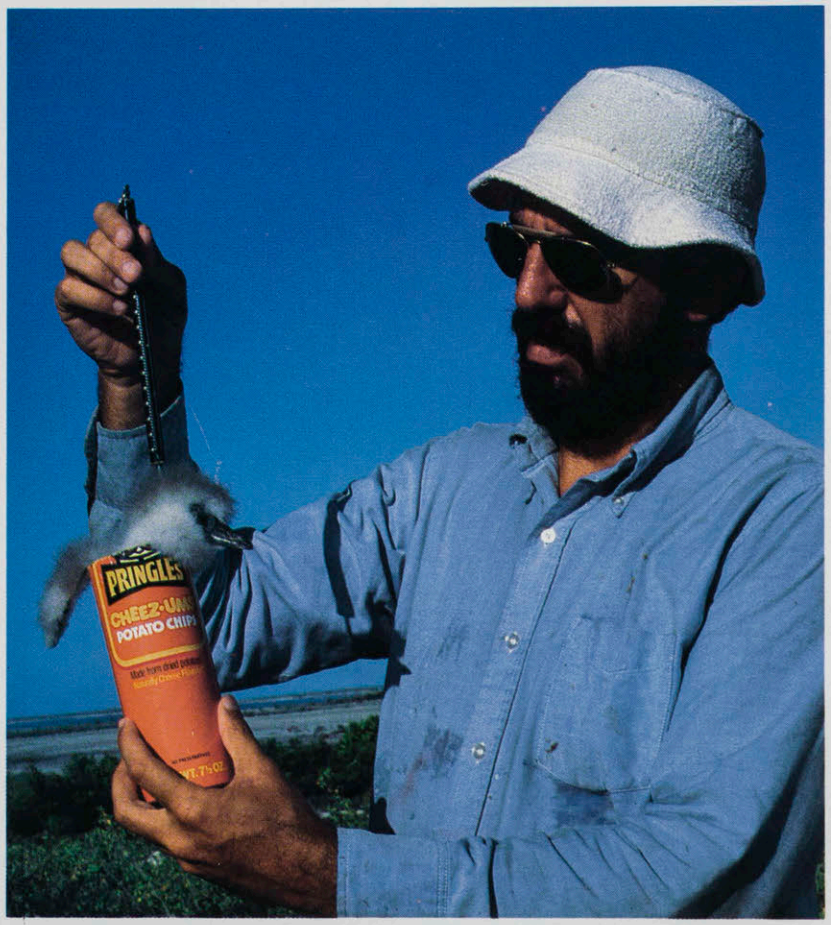
The birds on Johnston Atoll were much less severely affected. They do not feed in the equatorial upwelling and evidently only suffered a reduced food supply around their island and not a total loss. ENSOs cause a reduction in chick growth rates on Johnston Island because adults cannot catch enough fish to feed their young adequately. These underweight chicks may well die soon after leaving the nest because they begin their lives at sea underweight. While these young birds are trying to learn the difficult techniques of feeding themselves, they need an extra layer of fat on which to survive.

We continued to survey the birds on both islands in the following years and saw the populations beginning to grow again. But when we visited Christmas Island in October 1985, we found that Masked Booby chicks were starving, and fewer than normal numbers of adults were nesting. We could not believe that another ENSO was in progress–it seemed too soon. Yet the birds were responding exactly as they had before the 1982-1983 ENSO.

We checked in with Klaus Wyrtki again on our way home that year; he had no evidence of another ENSO episode. Ralph, being a truly conservative scientist, hesitated to tell anyone that the birds were predicting an ENSO. That was giving an awful lot of credit to some of the more primitive birds, when oceanographers were not finding any data that told them an ENSO was coming. But, sure enough, in January 1986 an ENSO watch was issued (National Weather Service, January 1986) three months after the Masked Boobies began experiencing the effects of a pertubation in the environment. One of the longest events ever known followed, lasting through 1986 and 1987. Christmas Island birds lost two years of reproduction, and birds on Johnston Atoll fledged underweight young again. Overall, the 1986–1987 ENSO was much less severe, and we believe that few adults died.

We do not know what the birds are responding to that makes them sense an ENSO before all of our advanced weather-forecasting technology. They probably begin experiencing difficulty in finding food due to changes in wind levels

Red-tailed Tropicbird in flight. Tropicbirds spend much of their lives flying over the open ocean. A young bird that did not have an adequate diet as a nestling would not survive its first year and learning to feed itself without extra reserves of fat. Chicks are left to starve if an ENSO begins during the breeding season; an underweight chick would soon die, and the adults themselves risk death, thus losing all possibility of future reproduction.



Late Curator of Ornithology Ralph W. Schreiber weighs a Red-tailed Tropicbird chick following the 1982–83 ENSO.

or in the upwelling areas where they feed. As the technology for measuring weather becomes more sophisticated, particularly with the advent of weather satellites, we hope to be able to find an answer to this question.

Seabirds have a vital reason for needing to know what changes in weather patterns mean. Weather changes can cause the disappearance of their food source, and they may die if they do not leave in search of new feeding sites soon enough. Because most of these birds probably live more than twenty-five years, it makes sense to abandon nestlings during these episodes or forego breeding for one or two years rather than risk death themselves.

This is why chicks are left to starve to death if an ENSO begins during the breeding season. If adults tried to raise chicks during times of scarcity, not only would they raise an underweight chick that would soon die, but they would risk dying themselves, thus losing all possibility of future reproduction.

Saving Lives and Surviving Droughts

The unexpected weather conditions that result from ENSOs have far-reaching effects: they have been linked to cyclones in the South Pacific, hurricanes in Hawaii, droughts in Ethiopia and India, and floods in Peru and California. There was a tremendous amount of publicity about our work on Christmas Island during the 1982–1983 ENSO, and we began receiving calls from people suffering the consequences of the ENSO, from farmers who were losing crops to droughts and from fishermen whose catches were affected. If birds could talk we might have been able to help those people in predicting the weather.

UNESCO's World Climate Research Program is conducting an international, long-term study of the oceans and atmosphere in an attempt to learn to predict ENSOs. With some advanced notice of these events, people could prepare for the dramatic weather changes that result.

I am continuing the research that Ralph and I started in the Central Pacific. In summer 1989 some of our Museum Members traveled with me to Christmas Island to survey the bird populations again. The work is rewarding although not always fun (boobies can give a nasty bite and do not always regurgitate their food directly into our collection bags).

But sadly, during our visit, we discovered signs that another ENSO might be coming. Few Masked Boobies were nesting; a few Red-tailed Tropicbirds were attempting to nest, but they were a month late. Both of these occurred before the last two ENSOs. Again, no oceanographic data indicated an ENSO was coming. However, in February 1990 the *Climate Diagnostics Bulletin* reported that current climatological events resemble those that occurred prior to the 1986–87 ENSO. By March 1990, oceanographers acknowledged that ENSO conditions existed in the Pacific Ocean. Once again, the birds were right and knew what the weather would do before we did.

In addition to following the birds' responses to ENSO events, we continue to learn more about their daily lives, knowledge that should help us preserve these spectacular members of our avian community. These species, with their great sensitivity to fish availability, can provide a valuable monitor of the productivity of our oceans. They can help us determine if pollution levels are increasing and reducing fish production. We too eat fish, and having a way to monitor this food source could be important to us. It appears we can learn a lot from watching our feathered friends.

Elizabeth Anne Schreiber is a Research Associate in the Natural History Museum's Ornithology Section.

A Bird in the Hand....

The Ornithological Collections of the Natural History Museum of Los Angeles County

by KIMBALL L. GARRETT

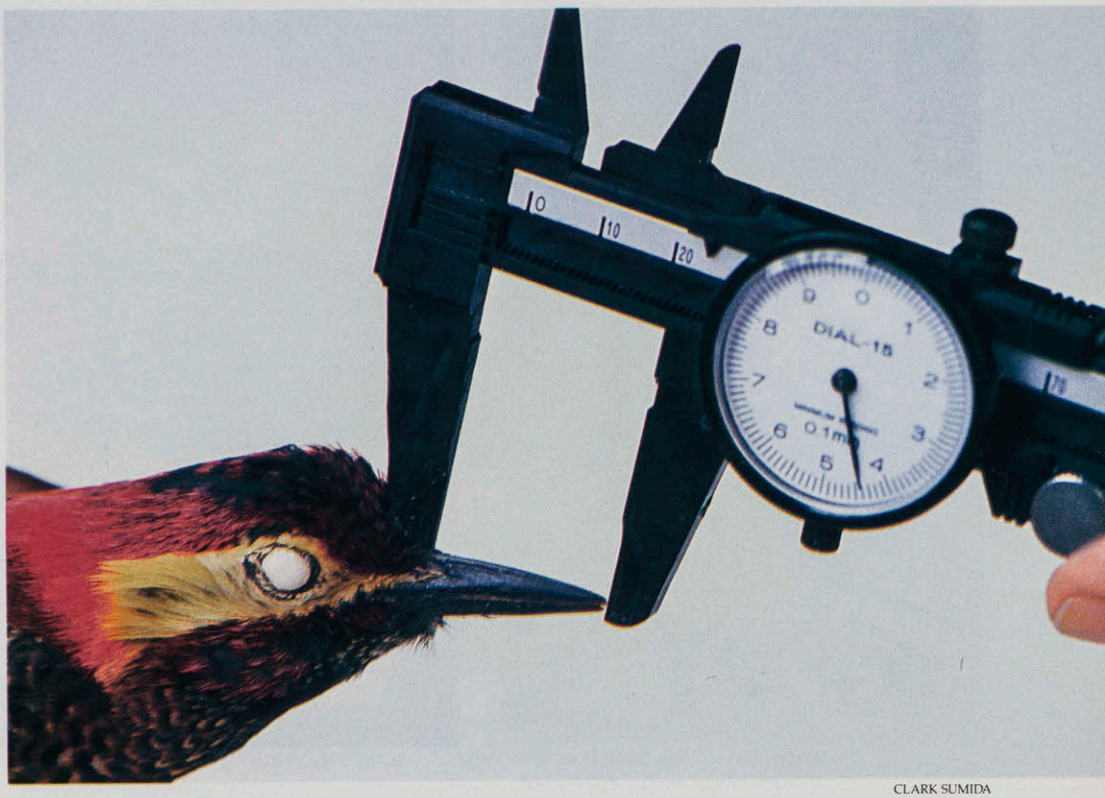
Visitors to our collections at the museum's annual Open House invariably ask "why do you have so many specimens of each 'kind'?" as they view row after row of similar-appearing specimens in the collection trays. The answer to this very valid question is twofold: in our collections we attempt to encompass the *variation* found within taxonomic groups; the larger the series, the more variation is captured. And, second, scientific analyses require statistically significant samples for rigorous study.

Both prongs of this explanation are illustrated by the analogy we often employ to answer our visitor's question. Imagine that ET, the Extraterrestrial, has visited Earth on a collecting trip for the Extraterrestrial Museum of Natural History, having been given the assignment of collecting *Homo sapiens* (that's us!). Whom should he collect? After your probable initial reaction of "Not me!", you are apt to reflect that there is no "typical" specimen of a human being. We see variation based on age, sex, geography, season (suntans, for example), and simple individual difference. These traits that we can detect and measure on a specimen are called *phenotypic* traits, which are, by and large, the representation of the underlying genetics superimposed upon the environment in which an individual has developed. Natural selection acts on phenotypes, so much of evolutionary science involves the analysis and comparison of phenotypic characters—such as those shown by bird skins and skeletons.

So whom does ET collect? Ideally, he obtains a sample encompassing these sources of variation that is extensive enough to accommodate the application of statistical tests and treatments.

Phenotypic variation in many bird species may be minimal to our eyes, but this is not to say that it isn't real and replete with evolutionary significance. The small flycatchers of the genus *Empidonax* look essentially identical to one another to all but the best-trained eyes. But adequate sampling from various regions at various seasons has shown that subtle characters—such as bill size, the relative lengths of the wingtip feathers, and the relative mobility of protein samples on a starch gel in an electric field—serve not only to differentiate some fifteen species within the genus but to demonstrate variation within and between populations of each of these species.

Superimposed upon the statistical ideals for a bird collection are, of course, the very real constraints of collection space, staffing, and funding. Even major collections like those at the Natural History Museum specialize geographically and taxonomically. The remark is often heard that an adequate series of specimens in a museum collection is one more than you already have. But a more important gauge of adequacy, albeit not always applied, is the number of specimens that can be properly cared for. The compactorized storage facilities at the Natural History Museum (see photo) are among the most modern of all ornithological collections. Data for all specimens have been stored in the Life Science Division's AlphaMicro computer, using CURATOR software.



CLARK SUMIDA

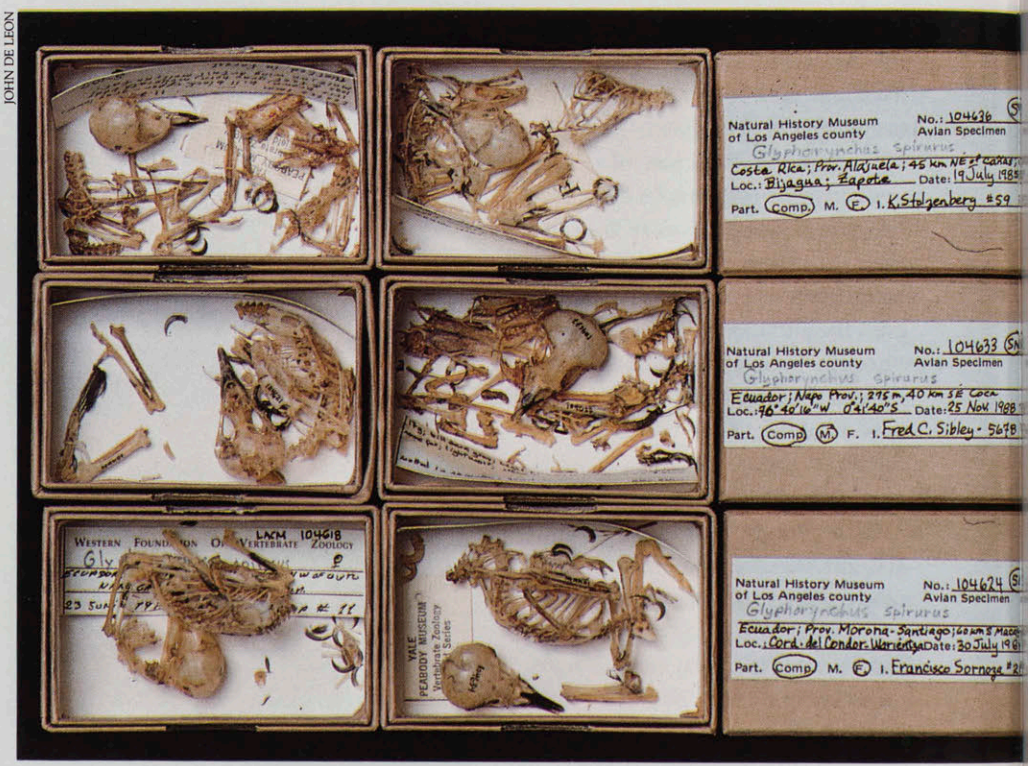
Careful measurements of specimens can provide a database for statistical analyses that in turn yield insights into the patterns of within-species variation. Here, the beak of a Crimson-mantled Woodpecker is measured using a dial caliper.

In the Beginning....

Museum bird collections have become worthy descendants of their progenitors, the natural history curiosity cabinets of the Victorian era. The scientific curiosities satisfied by the modern bird collec-

CLARK SUMIDA

Long-time volunteer and Research Associate Sharon Milder prepares a study skin of a Scrub Jay. The carcass is replaced with a cotton body wrapped around a stick.


Natural History Museum of Los Angeles county
No.: 104636
Avian Specimen
Glyphorynchus Spirurus
Costa Rica; Prov. Alajuela; 45 km NE
Loc.: Bijagua; Laguna
Date: 19 July 1985
Part. Comp. M. F. I. K. Stolzenberg #59
Natural History Museum of Los Angeles county
No.: 104633
Avian Specimen
Glyphorynchus Spirurus
Ecuador; Napo Prov.; 275 m, 40 km SE Coca
Loc.: 76° 40' 16" W 0° 41' 40" S
Date: 25 Nov 1988
Part. Comp. M. F. I. Fred C. Sibley - 5678
Western Foundation of Vertebrate Zoology
LACM 104618
Natural History Museum of Los Angeles county
No.: 104624
Avian Specimen
Glyphorynchus Spirurus
Ecuador; Prov. Morona-Santiago; 60 km S Macas
Loc.: Cord. del Condor-Warints
Date: 30 July 19
Part. Comp. M. F. I. Francisco Sornoza #2
YALE PEABODY MUSEUM Vertebrate Zoology Series

JOHN DE LEON

Bird skeletons are stored in boxes; the bones are mostly disarticulated. Skeletons are cleaned either by bacterial maceration or a colony of dermestid beetles.

tion are endless. Traditional inquiry into taxonomic relationships, geographical and seasonal status, and basic morphology and anatomy continues apace, but is complemented by increasingly sophisticated analyses at the molecular level and ever-widening application of research to conservation problems facing the modern world. And perhaps most exciting, museum collections constitute a resource that can ultimately answer questions that haven't even been articulated yet.

The Natural History Museum of Los Angeles County has been at the forefront of research institutions in western North America since its establishment in 1913; its ornithological collections rank among the most extensive and diverse in the world. The museum's first director, Frank S. Daggett, was an ornithologist; together with the staff ornithologists Luther E. Wyman and Harry S. Swarth, Daggett built up a collection of 14,400 catalogued birds when George Willett began his long tenure as Curator of Birds in 1927. (For more on history of Ornithology at the museum, see pp. 44–48.) The emphasis of the early collections was on western North America, particularly California, Arizona, and Alaska. Recurring collector names included Daggett, Willett, Swarth, and Hornung, along with collections by Austin Smith from Central America.

A period of great growth in the museum's collections occurred in the 1950s and 1960s under the curatorship of Dr. Kenneth Stager; during this period the Natural History Museum was directed by two well-known ornithologists: Jean Delacour and Herbert Friedmann. Extensive collections were made or purchased from South America and from east and central Africa. The National Science Foundation supported expeditions to Uganda in 1969 and 1970 that added more than 8,000 specimens. Also notable was the addition of John Williams's collection of sunbirds and shorebirds, totaling over 2,900 specimens.

Dr. Ralph W. Schreiber, Curator of Ornithology from 1976 to 1988, developed an emphasis on seabirds, particularly those of the Pacific Ocean. Over 3,000 seabirds were catalogued during this period. Schreiber also initiated a burgeoning of the Ornithology Section's anatomical collections during his tenure. An important collection of nearly 3,000 spirit specimens (preserved in ethanol) was almost entirely amassed under Schreiber's direction, and the skeleton collections more than doubled.

JOHN DE LEON

Typical "round skins" or "study skins" have been the mainstay of bird collections for nearly two centuries. They are stored on their backs in sealed steel cases.

A technique of preserving a "flat skin" and a complete skeleton of the same specimen has been regularly employed during the Schreiber era and to the present.

The Natural History Museum's ornithology programs continue to grow and diversify. At the start of the 1990s the ornithology collections of the Natural History Museum approached 105,000 catalogued specimens, representing individuals from about 55 percent of the world's 9,000+ bird species. A collection of viable tissues, stored in ultra-cold freezers for biochemical research, has grown to over 1,000 specimens in only two years. And, most important, the vast collections of the Western Foundation of Vertebrate Zoology are now administered by the Natural History Museum, bringing the world's largest collections of bird eggs and nests along with over 50,000 study skins and one of the largest ornithological libraries in North America.

Building the Collections

Specimens are obtained either through selective collecting or by salvaging birds found already dead. Research projects that involve the collecting and preservation of bird specimens often seek to settle taxonomic questions and reconstruct evolutionary histories. The Natural History Museum houses, for example, a collection of 126 gnatcatchers from the southwestern United States and northwestern Mexico (Jonathan L. Atwood) and one of 370 bushtits from Arizona, New Mexico, Texas, and Mexico (Ralph Raitt) that formed the basis of major published taxonomic revisions. Atwood's gnatcatcher study resulted in the recognition of the California Gnatcatcher as a species distinct from its desert sibling, the Black-tailed Gnatcatcher. In this case a taxonomic change has generated ecopolitical shockwaves, as the coastal sage scrub inhabiting California Gnatcatcher is rapidly disappearing under the booming urbanization of southern California. Field collecting may also answer ecological questions pertaining to diet, timing of molt, timing of breeding, and other natural history traits. As specimens are prepared, we routinely record such information as fat deposition, stomach contents, reproductive condition (as indicated by gonad development), and molt. Even parasites may be saved for subsequent analysis. Our extensive recent collections of seabirds from the eastern and central tropical Pacific Ocean have contributed just this sort of information

WHAT KINDS OF SPECIMENS ARE IN THE COLLECTIONS?

Study Skins ("Round Skins")	93,000 (plus 50,000 from WFVZ)
Flat Skins	1500
Alcoholics (complete specimens fixed in formalin and preserved in ethyl alcohol)	2900
Skeletons	7300 (5600 complete)
Life Mounts	1500 (including those transferred to museum's education division; many additional mounts in new Hall of Birds)
Egg sets	165,000 (WFVZ)
Nests	12,000 (WFVZ)
Frozen Tissues	1000

JOHN DE LEON

We have prepared over 1,000 "flat skins" at the Natural History Museum; this preparation allows close examination of molt and feather tracts and is accompanied by a complete skeleton.

JOHN DE LEON

"Spirit" or "alcoholic" specimens are stored in ethanol after fixation with formaldehyde; they are especially useful for anatomical research.

for a group of birds notoriously difficult to study.

General avifaunal collecting documents the bird life of a given region in addition to providing the raw material for numerous other avenues of inquiry. Such collections are especially important when they represent habitats subsequently destroyed by deforestation or other environmental change. More than 12,000 skins from Misiones Province in Argentina and 8,000 skins from several Ugandan forests reside at the Natural History Museum of Los Angeles County—all of these collecting localities have now been thoroughly deforested. One of the world's most important collections of Bornean birds was made by the Western Foundation of Vertebrate Zoology and again represents regions now severely altered by deforestation.

Zoological parks in Los Angeles, San Diego, and elsewhere provide many specimens for research and exhibit, and we have also enjoyed the cooperation of many private aviculturalists. Important local sources of specimens continue to be window kills, road kills, and other mortalities salvaged by the public. The number of birds killed annually by collisions with windows has been estimated to be up as high as 976 million per year (Klem, D., Jr., "Collisions between birds and windows: mortality and prevention," *Journal of Field Ornithology* 61: 120–128, 1990).

"So How Are These Things Used, Anyway?"

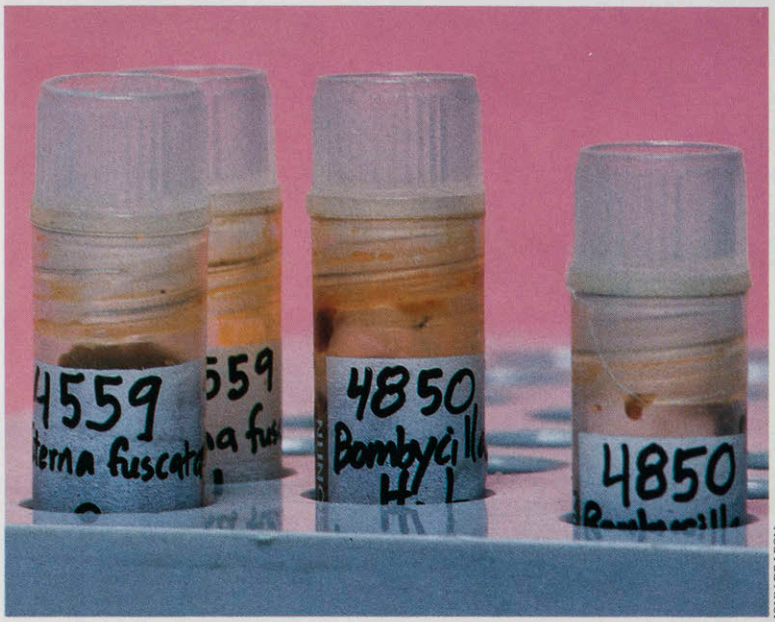
It is one thing to amass and maintain a sizeable bird collection.

WHERE DO THE SPECIMENS ORIGINATE?

North America	33,800
South America	33,300
Africa	25,900
Eurasia	2,600
Australia	500
Pacific Ocean/ Antarctica	3,100
Other regions, zoos, no data specimens, etc.	6,000

But the true scientific worth of a collection is measured, ultimately, in the extent to which the collection's components are cited in scientific publications. The research approaches applied to bird collections are astonishingly varied. A sampling of recent titles from the scientific literature that were based in part on our collections includes:

- "Geographic variation in the Yellow-billed Cuckoo"
- "A phylogeny of the thirty-two genera in the *Elaenia* assemblage of tyrant flycatchers"
- "Morphometrics of flightlessness in the Alcidae"
- "Moults of rectrices and body plumage of Blue-eyed and King Shags (*Phalacrocorax atriceps* and *P. albiventer*) and phenology of moults"
- "Range extensions for some Bolivian birds"
- "Field identification of smaller sandpipers within the genus *Calidris*"



JOHN DE LEON

JOHN DE LEON

Left: Freshly removed heart, liver, and pectoral muscle tissues are stored in these "nunc tubes" in an ultra-cold freezer; future analysis may yield information on population genetics, phylogenic relationships, and environmental contaminants.

Above: Study skins of birds and small mammals are housed in steel cases on this compactorized storage system of movable aisles. Renovations to the Sections of Ornithology and Mammalogy at the Natural History Museum were completed in fall 1989.

WHAT DO I DO WITH A DEAD BIRD?

1. KNOW THE LAW. Possession of nearly all native bird species, dead or alive, is illegal without proper permits issued by the United States Fish and Wildlife Service and other agencies. This pertains to bird parts, nests, and eggs as well.

The Natural History Museum of Los Angeles County and many other similar institutions not only maintain permits to possess such species but have agreements with wildlife enforcement agencies that allow them to receive salvaged specimens from the public. It is not unlawful, therefore, to salvage birds found dead for the purpose of donating them directly to the Natural History Museum.

2. LABEL THE SPECIMEN. Affix a tag to the specimen; use durable paper and write with permanent ink. On this tag provide the following information:

- date found
- exact locality
- condition when found
- other details (cause of death if known, habitat, color of eyes, bill, legs, feet, etc.)
- your name and address

3. FREEZE THE SPECIMEN; place it in a sealed plastic bag and into a freezer.

4. CONTACT AN ORNITHOLOGY STAFF MEMBER. Arrangements may then be made to get the specimen(s) to the museum. If frozen soon after death, specimens can make excellent skins or other research material even after years in a freezer (if sealed in a bag).

Remember that museums have acquisition policies that may not allow them to accept unlimited numbers of specimens. Acceptance of specimens will be at the curator's discretion and in accordance with stated museum policies. The Ornithology Section's phone number is 213/744-3368.

Collections of bird specimens represent invaluable reference material for bird artists. This painting of flycatchers for an identification guide in preparation was based on actual specimens. Painting by Jonathan Alderfer.

JOHN DE LEON

JOHN DE LEON

"Why so many of each kind?" These bulbuls* (Pycnonotus latirostris) *may all look alike, but such large series of specimens in fact reveal a wealth of information about geographical and seasonal variation, plumage development with age, individual variation and many other evolutionarily significant patterns. Additionally, they document geographical distribution.

And here are just a few examples of the kinds of requests we receive for collection-based information:

- Printout of all owl specimens from Mexico
- Identification of hawk and owl feathers found in a local yard
- Photographs of spread wings of *Pterodroma* petrels
- Weights of Brown Noddies
- Specimens of Cerulean Warblers from wintering grounds in the neotropics
- Specimens of birds from Socorro Island, Mexico
- Printout of specimen holdings of downy young waterfowl

Our collections serve a constituency that goes well beyond the research scientist. Bird artists striving for accuracy, birdwatchers checking field identification criteria, and environmental planners investigating such things as nesting dates and habitat associations of birds in a given region use our collections and associated data regularly. Agents enforcing wildlife laws rely heavily on our collections for identifications.

The Future

Museum collections form the foundation of the broader goals of the institution: research, education, exhibition, and publication. The sensible acquisition of specimens and their subsequent care and conservation are ongoing activities in all museum collections. With newly renovated collections facilities, a formal association with the Western Foundation of Vertebrate Zoology, and an exciting new Hall of Birds due to open soon, this is an exciting phase in the long history of ornithology at the Natural History Museum of Los Angeles County. And with natural habitats diminishing daily around the world, our bird collections take on an ever-increasing importance in our endeavor to understand and learn from the diversity of life on the planet.

Kimball L. Garrett is Collections Manager of the Ornithology Section of the Natural History Museum.

How Big was It?
Determining the Size of Ancient Birds

by KENNETH E. CAMPBELL and LESLIE MARCUS

Size is a quality of every living organism, a quality we frequently express in terms of volume or bulk. The size of an organism is seldom constant, however, because many factors interact to influence it at any given time. Size changes as an organism grows; it differs between periods of good health and bad; it may vary daily or seasonally; and it certainly varies with the availability of food. Although the size of living organisms is often expressed in terms of volume, obtaining a true measure of volume is quite difficult because the shapes of living things do not lend themselves to easy measurement.

For this reason, the size of an organism is frequently expressed using linear measurements, such as height, length or width, often in combination with weight. Determining linear measurements is relatively easy for living and fossil organisms, and living organisms can be weighed. However, reliable estimates of weight for fossil organisms are particularly difficult to determine, and many weights ascribed to fossil animals are little more than guesses, some perhaps a little more educated than others. This is because frequently so little of an animal is preserved or because the fossil may represent an organism without a close living relative to guide us in estimating its weight. For vertebrates, usually only the hard parts such as teeth and bones, and none of the soft parts that make up most of the weight of a living organism, are preserved. To paleontologists, determining the weight of fossil animals is important because it is often a clue to the life habits of the animals they are studying. Weight may, for example, give hints about the bodily structure of the animal and how it moved, growth rates, size at birth or hatching, or food requirements, which in turn may tell something about home range, time spent in feeding activity, or ecosystem carrying capacity.

Actually, instead of the term *weight*, scientists prefer to use a measure termed *mass*, which is equal to the weight of an organism divided by the acceleration due to gravity. In this article we will use weight as our measure, not mass, because our purpose here is explore ideas, not present technical arguments.

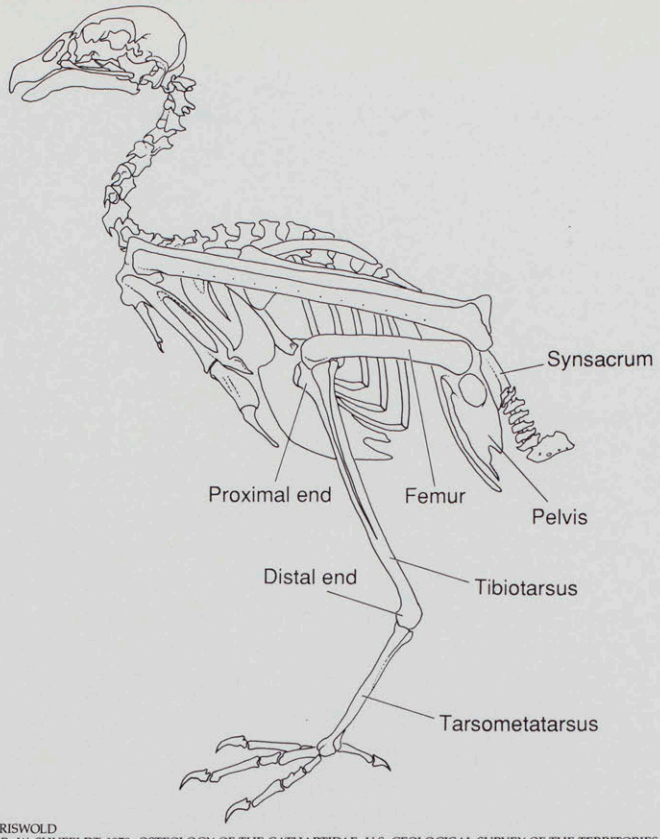
One of us (KEC) became interested in determining the weights of fossil birds when involved with describing a giant bird from Argentina, *Argentavis magnificens* (see TERRA, Fall 1980). This bird was estimated to have had a wingspan of about 6–8 meters (20 to 26 feet) and to have stood about 2 meters (6.5 feet) tall. The presence of normally proportioned wing bones indicated that *Argentavis* was a flying bird, by far the largest known. The determination of the weight of this bird became more important than in the normal study of fossil birds because it was the world's largest known flying bird. This flying bird obviously had not reached the upper limit of size for flying birds, but was it near that limit? How heavy can a bird be and still fly? Knowing the weight of *Argentavis* would not necessarily answer these questions, but if we had a reliable weight estimate for *Argentavis* we would be much nearer an answer than we would be if the fossil of *Argentavis* had never been found. Just guessing a figure would not do.

Fortunately, at about that time some colleagues at the University of Florida were studying the relationships between weights of birds and their skeletal weights. They were able to destroy one oft-repeated myth about bird skeletons and at the same time they provided a basis for predicting the weights of fossil birds. The myth was that because some bird bones are hollow, bird skeletons are lighter than the skeletons of mammals. What they found instead was that the weights of the complete skeletons of birds and mammals are the same, for birds and mammals of equal live body weight. (The phrase *live body weight* refers to what the animal weighed when it was living. For scientific specimens this usually means what the animal weighed at the time it was collected.)

What they also provided was the fact that there is a predictable relationship between the size of a bird's leg bones and its weight. They found a relationship between live body weight and both the length and shaft circumference of the femur—that is, the thigh bone of a chicken. Acting on this discovery, Campbell measured the leg bones of 324 birds of known weight that ranged in size from 3-gram (0.1 ounce) hummingbirds to 160-kilogram (352 pound) ostriches. Unfortunately, the femur of *Argentavis magnificens* was not known. It was therefore necessary to measure the circumference of the tibiotarsus, the bone that is in the drumstick of a chicken, to see if there was also a close correlation between it and

Left: **Argentavis magnificens,** *a member of the extinct Family Teratornithidae discovered in Argentina, lived 5 to 8 million years ago. Teratorns, which are very common in the La Brea Tar Pits, were related to storks and New World vultures.* **Argentavis,** *with its wingspan of 6 to 8 meters (20 to 26 feet), is by far the largest-known flying bird. Determining the weight of this immense bird helps establish how heavy a bird can be and still fly. It probably weighed up to 79 kilograms (175 pounds).* **Argentavis** *is compared here in size to a Bald Eagle.*

MIKE MEAKER



WENDY SMITH-GRISWOLD
REDRAWN FROM R. W. SHUFELDT, 1878, OSTEOLOGY OF THE CATHARTIDAE, U.S. GEOLOGICAL SURVEY OF THE TERRITORIES

The three principal bones of a bird's leg are the femur, tibiotarsus, and the tarsometatarsus. The femur supports the weight of the bird at the point where its proximal end connects with the pelvis, but the bird's center of gravity lies forward of the pelvis. Consequently, the femur is normally held near a horizontal position so that the distal end of the femur always remains under the center of gravity, thereby allowing the bipedal animal to maintain its balance. The knee of a bird is normally hidden from view by the skin and feathers of the body. The "knee" that points backward is actually the bird's "heel."

the live body weight of the bird. These data were used to construct a mathematical equation that described the relationship between the circumference of the tibiotarsus shaft and bird body weight. It then became possible to insert measurements from the tibiotarsus of *Argentavis magnificens* into the equation to estimate the weight of that giant bird. The resulting prediction was that *Argentavis magnificens* weighed 78.8 kilograms (174 pounds), a very heavy flying bird indeed!

As usual, however, coming up with an answer to one scientific problem led to many more questions. For example, why *is* there a predictable relationship between the dimensions of a bird's leg and its live body weight? Would the results be the same if data from many more birds were included in deriving the prediction equation? Are there any differences in the observed relationship among various evolutionary lineages of birds or among groups of birds that are functionally different? Are some leg bones better predictors of weight than others? Is the relationship sufficiently established so that the weights of any kind of extinct bird can be predicted? Does the relationship seen in birds hold any promise for predicting the weights of other kinds of extinct animals?

Birds live on almost all lands and in most seas of the earth, and they have evolved a fantastic variety of forms to cope with their environments. Besides the common songbirds with which everyone is familiar, there are birds that live almost exclusively in water, coming out only to lay eggs and raise their young. There are seabirds that fly almost all year long without stopping, landing only long enough to lay eggs and raise their young on shore. There are giant emus and ostriches that weigh hundreds of kilograms, have big legs and feet and cannot fly, and tiny hummingbirds that weigh only a few grams, have tiny legs and feet and can "fly," or hover, in place. The list of extremes and fascinating lifestyles could go on for pages. Regardless of how or where birds may live or what they may look like, however, they are always immediately recognizable as birds.

The variety of birds suggests that it would be difficult to find a single bone that would have a constant relationship to body weight throughout the class. Skull bones are not good candidates because they vary in size and shape, even for birds of the same size, depending upon what the bird eats. Since birds eat a variety of items, from nectar, seeds and leaves to insects, eggs, fish, carrion, or even other birds, the variation in skull bones is considerable. Wing bones and breastbones will not work because many birds do not fly. Foot bones will not work because various birds have different numbers of toes with a variety of different shaped bones, corresponding to their wide variety of adaptations. Vertebrae may work, but they are very fragile and are seldom well preserved as fossils.

The two bones in a bird's skeleton that have the least variation in general form and structure from one kind of bird to another are the femur and tibiotarsus. Of these two, the femur would appear to be the better indicator of body weight because its principal function is to provide support for the bird's body weight and its shape is therefore more conservative. The tibiotarus provides support for the body as well, but it also plays an important role in locomotion and consequently its shape is often modified for that function. The tarsometatarsus, the leg bone that you never see on a table chicken, not only provides

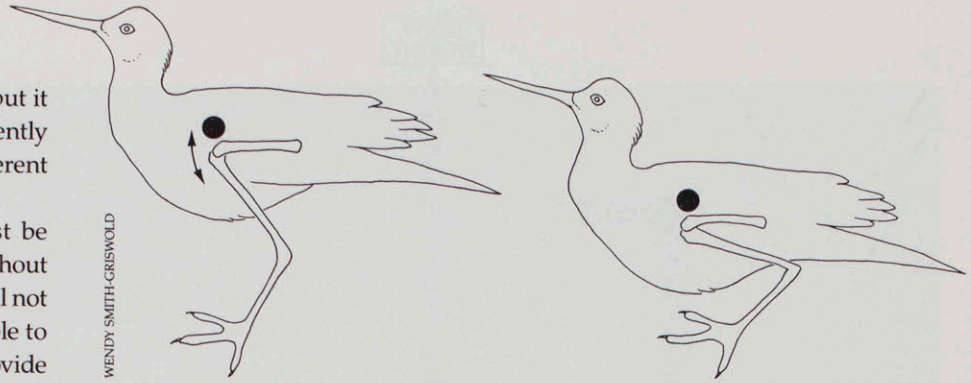
support and serves a locomotory function, but it often serves a role in feeding and is consequently often much modified for a series of different functions.

To serve its support role, the femur must be sufficiently large to support the body without breaking, as a bird with a broken leg bone will not live long. On the other hand, it is not desirable to have a bone larger than is necessary to provide support, plus perhaps a small safety factor, because the excess would always have to be carried around; and the bird would have to eat more to provide the necessary energy to maintain this unnecessary excess. Food is often in short supply for animals and this could lead to an unsatisfactory situation.

To understand why the femur's close relationship to the weight of a bird exists, it is necessary to examine how a femur performs its support function. All birds are bipedal, that is they have only two legs, the hindlimbs, for support or locomotion on land. The forelimbs are modified into wings for flying and cannot be used for these purposes, although sometimes they are used to help in clambering about in bushes. In flightless birds, of course, the wings tend to be considerably reduced. Maintaining proper balance when you have only two legs for support and locomotion, instead of four, is a difficult engineering design problem.

Humans are bipedal, and we often have balance problems. Human bodies tend to be elongated vertically, hence our weight is concentrated over our hips, where the legs attach to the body. Bird bodies, however, tend to be elongated horizontally, and the weight is concentrated forward of the place where the legs are attached to the body. If a bird's legs attached to the body like they do in humans, that is, if the femur were in a vertical position, a bird would fall flat on its face, or bill, every time it tried to stand up.

Why, you might ask, are bird legs not centered under their body so that the femur could be held vertically? The answer may lie in the fact that when the first birds started flying, two mechanical adaptations had to evolve. One was getting as big a boost into the air as possible before they began to flap their wings, and the other, which is perhaps more important, was overcoming or absorbing the physical shock of the impact of landing. Birds can accomplish both of these functions by keeping their leg bones in an approximate Z-configuration, although some terrestrial



Above: The bones of a bird's leg are normally held in a Z-configuration, with the distal end positioned under the bird's center of gravity. The double-headed arrow indicates the small arc through which the femur can move, an arc that keeps the distal end of the femur under the center of gravity so that the bird can maintain its balance.

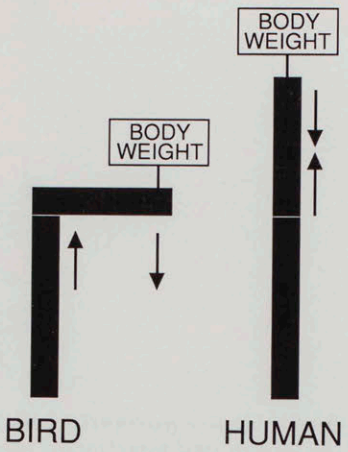
When a bird squats in preparation for jumping into the air or from one perch to another, the Z-configuration of the leg bones compresses, an action that provides the bird with greater "spring" when it jumps.

birds, especially those with long legs, may hold their lower leg bones in more of a vertical position. It may be that for walking a vertical configuration of the leg bones is best and for the other functions you need another configuration—and it is difficult to optimize both.

You can test how important a Z-configuration of the leg bones is for birds. Stand erect holding your legs in a vertical position and, without bending your knees, try to jump. You should find that you cannot leave the floor. Then, bending your knees, jump an inch into the air and lock your legs into a vertical position before landing. You should feel a sizable jolt pass through your entire body on landing, a jolt that you do not feel if you bend your knees when landing. You will notice that the more you bend your legs at the knees, the higher you are able to jump and the softer the landing. This will be especially true if you activate an additional joint by raising your heel off the floor and jump and land on the ball of your foot.

Look carefully the next time you see a bird take off. Note that just before it jumps from one perch to another, or leaps into the air, the bird drops its body closer to its perch, or the ground. It then literally "springs" into the air as it jumps or takes off.

Another important bone in this system is the synsacrum, which is formed by the fusion of a number of vertebrae into a solid bony structure. The synsacrum is in turn very tightly bound to the pelvic, or hip, bones, and the overall structure gives a large, rigid platform for distributing the



AFTER MCMAHON AND BONNER

The femur of a bird acts as a cantilever, supporting the weight of the bird at its proximal end while being supported in turn by the tibiotarsus at its distal end. This results in large bending forces being applied to the bone and explains why there is a strong relationship between the circumference of the femur and the weight of the bird. In contrast, animals that hold their leg bones in a vertical position experience compressive forces on the femur. The two different types of forces, bending and compressional, affect bone in different ways, so femora designed to withstand one type of force may not be able to resist breaking under an equal amount of the other type of force.

Reliable estimates of weight for fossil organisms are particularly difficult to determine, and many weights ascribed to fossil animals are little more than guesses.

forces of landing and taking off. This platform, which varies widely in size and shape among the different types of birds, is also important in providing a solid anchor for the pelvic musculature that helps to move the leg. The proximal end of the femur attaches toward the middle or rear of this platform; exactly where differs widely among species of birds.

When a bird is standing, its femur is usually almost in a horizontal position, extending toward the front of the bird. As alluded to earlier, the weight of any bird, and thus its center of gravity, is concentrated in front of where the femur attaches to the body. A bird maintains its balance and does not fall on its face because the distal end of the femur is at or slightly in front of its center of gravity. The larger the bird, the farther the center of gravity is from where the femur attaches and the longer the femur has to be in order to extend under it. In this way we can explain why there is a relationship between the length of the femur and the weight of the bird.

How a bird's femur moves is also important and often misunderstood. When a bird is walking or running, its femur does *not* swing *back and forth* as it does in humans or in quadrupeds like horses. Instead, the distal end swings *up and down*, above and below a nearly horizontal plane defined by the distal end of the femur in a standing, at rest, position and the stationary point of attachment of the proximal end of the femur to the pelvis. If the distal end of the femur goes behind the center of gravity, the bird becomes very unstable and it can lose its balance and fall. The arc that the femur passes through is, therefore, very limited.

The movement of the femur is hard to see in most birds because their feathers and wings effectively hide it from view. It is easier, but still not easy, to see how the femur moves by observing large ratites, like ostriches or rheas, walking rapidly or running. They can be observed in many zoos.

It is the lower leg, comprising the tibiotarsus, tarsometatarsus, and foot, that moves back and forth when a bird is walking or running. This is the only part of the leg that you see when you watch a bird walk or run. A bird's stride, or length of step, is determined by the length of the tibiotarsus and tarsometatarsus. The longer these bones are, the greater the stride and the faster they can run. So, for birds adapted to a cursorial, or running, lifestyle, the length of the tibiotarsus and tarsometatarsus will not have a direct relationship to body weight.

The reason why the diameter or circumference of the femur closely reflects the weight of a bird also becomes clear when its support role is analyzed. The femur functions as a cantilever, supported by the tibiotarsus at one end and in turn supporting the rest of the bird at the other end. The leg is kept from collapsing by muscles and tendons. The femur experiences its greatest stress when it passes through the horizontal plane, and therefore it must be sufficiently large so as not to break when in that position. That part of the shaft of the femur that is of the smallest circumference will be the weakest part of the bone. Thus, a measure of that dimension should be an accurate reflection of the weight of a bird.

For similar reasons, the least circumference of the tibiotarsus also reflects a bird's body weight. One might suspect that the tibiotarsus would not be quite as good an indicator of a bird's weight because the tibiotarsus experiences a greater variety of forces than does the femur. However, a comparison between the least shaft circumferences of bird femora and the least shaft circumferences of tibiotarsi shows that there is an extremely high correlation between them. If you know the measurement for one of these two bones, you can predict that of the other with high accuracy. So, if you have the tibiotarsus of an extinct bird, but not its femur, as was the case

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with *Argentavis magnificens*, you can use its circumference as a reliable indicator of the fossil bird's weight.

Or can you? There is still the question as to whether or not the described relationship between the least shaft circumference of the femur and tibiotarsus and the live body weight holds for all kinds of birds. To study this question further, Campbell's original data set was expanded from 324 individuals of 19 orders and

Moas were giant flightless birds that lived in New Zealand; they are now all extinct. The largest moa was* Dinornis maximus*, which stood 3.6 meters (12 feet) tall and weighed up to 300 kilograms (660 pounds). The bird's weight when alive was determined by comparing the size of its leg bones with the size of the leg bones of birds with known body weights. This reconstruction was painted by Charles Knight. Note that the manner in which the legs were reconstructed in this painting is inconsistent with our current understanding of avian anatomy and locomotion.

Birds have evolved a fantastic variety of forms to cope with their environments.

45 families to 803 individuals of 25 orders and 89 families. The enlarged data set also provided the opportunity for us to question how homogeneous the data really were and to test whether they were consistent with the mechanical laws that have been proposed to explain the relationship. A comparison of the logarithmic plots of the two data sets shows a very close similarity between them, but also some differences. Using the mathematical equation derived from the expanded data set gives a predicted weight of 71.9 kilograms (158 pounds) for *Argentavis magnificens*, compared to the original estimate of 78.8 kilograms (174 pounds). The difference of 6.9 kilograms (16 pounds) between the two estimates may appear large, but it is actually a very good result.

Using the new equation we attempted to estimate the weights of some other very interesting fossil birds, including the Dodo, the Elephant Bird of Madagascar, and two moas from New Zealand. The predicted weights, based on measurements of the femora, ranged from 13.2 kilograms (29 pounds) to 16.4 kilograms (36 pounds) for the Dodo (*Raphus cucullatus*), the famous extinct bird from Mauritius Island in the Indian Ocean. Measurements from eight femora of the Elephant Bird (*Aepyornis maximus*), which had a very stocky build and may have stood 3 meters (10 feet) tall, gave results of 333 kilograms (732.6 pounds) to 663 kilograms (1,459 pounds), with an average of 526 kilograms (1,158 pounds). Two specimens of the largest known moa, (*Dinornis maximus*), which may have stood 3.6 meters (12 feet) tall, gave results of 245 kilograms (539 pounds) and 299 kilograms (658 pounds). And estimates based on two specimens of *Pachyornis elephantopus*—perhaps the most heavily built moa, but one that stood only about 2 meters (6.5 feet) tall—ranged from 180 kilograms (396 pounds) to 211 kilograms (464 pounds).

Are we satisfied with the weight estimates for the birds mentioned above? No. There is still too much possibility for error in the estimate. If we had more data for putative relatives of *Argentavis* or more data for birds of presumed similar habit, we would be much happier with our estimates. Also, if *Argentavis magnificens* were a much smaller bird we would have greater faith in the estimate of its weight. Why? Because there are very few species of very large flying birds living today, and they are not well represented in our data.

Further, the Elephant Bird and the two moas were gigantic flightless birds, and it is very difficult to obtain data for the largest living birds that approximate their body build, the ratites, just because they are very large. Whenever specimens of ratites were collected and the skeletons put into museum collections, they were almost never weighed because it was too difficult. Scales for weighing these giant birds, that in the case of ostriches may weigh as much as 160 kilograms (350 pounds), were just not common items in ornithologists' field bags, nor are they today. Although we have made numerous attempts to locate data on these large birds, skeletons with weight data are very rare in existing museum collections—we have only been able to find two! It will require special museum expeditions to gather this information, perhaps even from ostrich or emu farms where these giant birds are raised commercially.

We suspect that if such data were available and added to what we already have, our estimate of the weight of *Argentavis magnificens* would be greater than that currently predicted because the prediction equation now available is based mainly on small birds. On the other hand, *Argentavis* was a flying bird and data from giant ground birds may not give us a reliable estimate because they may affect the prediction equation in an as yet unknown manner. One thing we do know, however, is that with data from ratites we would be able to test the reliability of our estimates for the Elephant Bird and the moas.

If we wished to delve even deeper into questions of size we might ask: what is the relationship between the size of a supporting skeletal element and the weight it must support—from the standpoint of the laws of physics and strength of materials?

If we compare two different-sized organisms of exactly the same shape, we may ask how they will differ in weight. A very naive person might suggest that if one organism is twice as long, twice as tall, twice as wide and is twice as large in every other dimension it will weigh twice as much. We will explain how wrong this is!

It is easy to recognize that if all the linear dimensions of an organism increased proportionally—that is, if it becomes twice as tall, twice as long, and twice as wide—then its volume and thus its weight will increase by a factor

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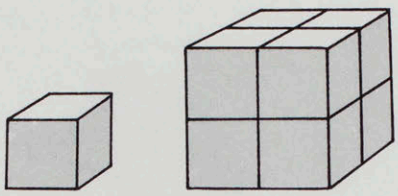
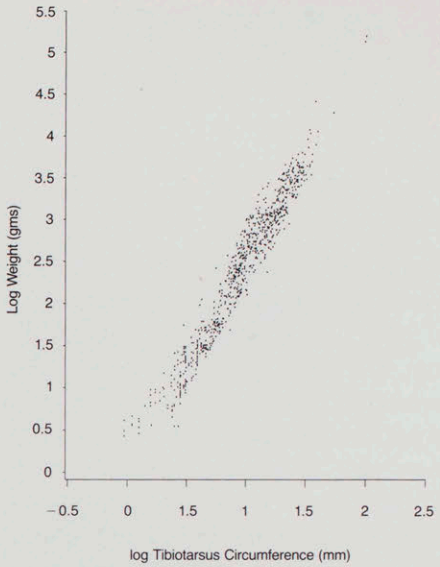
*The extinct Elephant Bird of Madagascar (***Aepyornis maximus***) was shorter than* **Dinornis** *(page 37), but it was stockier. It was around 3 meters (10 feet) tall and weighed up to 663 kilograms (1,459 pounds). In contrast to the reconstruction of* **Dinornis**, *this painting of* **Aepyornis** *is a more accurate reflection of avian anatomy and locomotion.*





If the linear dimensions of an object are doubled, the volume of the object is increased by eight times. Although we use a simple cube to illustrate this, it is just as true for living organisms of all shapes.

Right: This graph illustrates the high correlation between the logarithm of the weight of a bird and the logarithm of the circumference of its tibiotarsus across the whole spectrum of bird diversity, from tiny hummingbirds to giant ostriches and from fliers to nonfliers. Data from almost 800 birds in 25 orders and 89 families are represented on this graph. The correlation coefficient is 0.944.

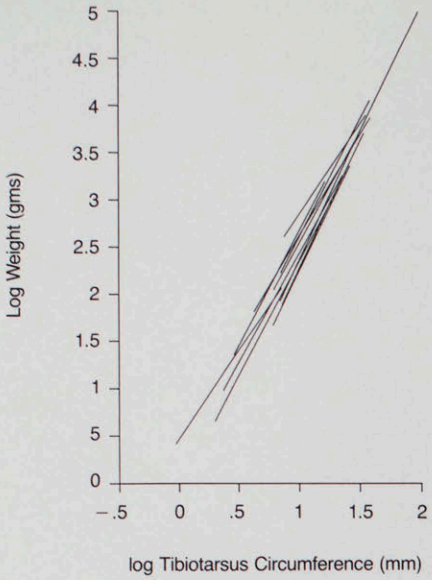
of 8. This would mean that a leg bone only twice as thick would have to support 8 times the original weight. Clearly, there must be some other factors at play here.

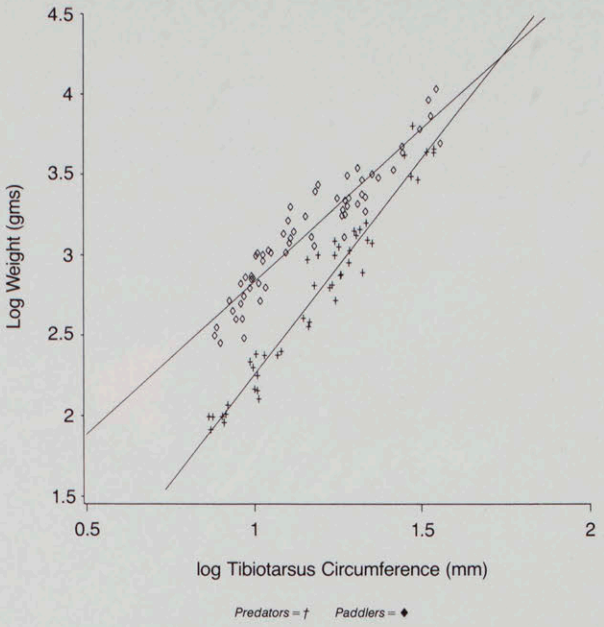
One of these factors is that the critical feature of the supporting bone is its cross-sectional area, not its thickness. If the diameter of a bone increases by a factor of 2, its cross-sectional area increases by a factor of 4. But this is still not enough to compensate for an increase in weight by a factor of 8. The new cross-sectional area must also increase by a factor of 8 to resist crushing! To achieve this larger size, the supporting leg bone of our twice taller organism must have a diameter, or circumference, 2.8 times larger than the original; 2.8 × 2.8 is approximately 8. The larger organism would thus have to have thicker legs than a simple proportional increase would predict, and the legs would have a different shape. This is obvious when we compare, for example, the legs of a deer and an elephant.

Let's look at this problem again with yet a larger size difference. Let us compare a small songbird like a sparrow to a large, ostrich-like bird. Let our large bird be 30 times as large as the small bird—30 times in each dimension. Suppose our sparrow-size bird weighs 10 grams and has supporting leg bones 1 millimeter in diameter. Our scaled up bird will then weigh 30 × 30 × 30, or 27,000 times as much—or 270,000 grams (270 kilograms)—as our 10-gram sparrow. This discussion assumes that all other things—such as posture, strength, and thickness of bone and habit—are equal. An ostrich, of course, is not built the same way as a sparrow and they do not weigh anything like 270 kilograms. We will see some of the reasons why.

As we have seen, larger organisms do have thicker limbs than predicted by simple proportional increases in size. In the last example, an increase in the diameter of the leg bone to 30 millimeters would not be sufficient to support the new weight because the cross-sectional area would only increase about 700 times. However, if the cross-sectional area of the supporting leg bone were to increase 27,000 times to match the 27,000 times increase in weight, it would have a diameter of about 185 millmeters (about 7 inches), and no bird is built like that. In fact, if we were to keep following this line of reasoning, the bone would eventually be wider than long! Something is wrong. We know that bones are not as thin or as thick as these two models would suggest.

We pointed out earlier that the femur must resist bending rather than crushing, or compressional, force. That is, the femur acts as a cantilever and not a pillar. If we model a cantilever like a bird femur, it turns out that when a bird is 30 times larger in most of its dimensions, its femur needs to increase in thickness by more than 30 times but less than 185 times in order to be strong enough to resist bending and breaking. Models based on bending rather than compressional forces suggest a mathematical relationship between the diameter of a supporting member and body weight. These models predict that weight will be proportional to the 2.7 power of diameter or circumference. Using this model the bird 30 times larger would have a leg bone 46 millimeters in diameter. However, a femur diameter of 45 millimeters has been measured for an ostrich that weighed only 160 kilograms, or far less than 270 kilograms. Clearly, these models, in and of them-





Left: Although there is a high correlation between weight and leg bone size when all birds are analyzed together, analysis of subsets of the data reveals that slight differences exist among different groups. Eleven subsets of the data are represented by the lines in this graph. The subsets were defined as groups of birds that were either closely related phylogenetically or that were similar morphologically. We do not yet know why these several subsets of the data differ from each other.

Above: The details of two subsets of the data are shown in this graph. The diamonds represent paddling birds (ducks, geese, and swans) whereas the crosses represent predatory birds (falcons, hawks, and eagles). It can be seen that the smaller members of each of these groups are the most dissimilar and that the two groups approach each other as larger members are compared. We do not have a clear understanding why these two groups differ from each other.

selves, do not accurately represent how living things are really built. We must base our estimates on actual data and not models.

As we have seen, this oversimplified kind of thinking or modeling, so popular in science, does not solve our problem, but it provides guidelines and boundary conditions for our thinking and serves as a check on our computations and data.

When we examined our bird measurements more closely, looking at subgroups of birds related by descent or having similar habits, we found that the separate groups were not as similar as the original graphs and high correlation might suggest.

When we look at a graph of paddling birds (ducks, geese, and swans) and predatory birds (falcons, hawks, and eagles), we see that they follow different, but at the same time related, patterns. The pattern for the paddlers fits a compressive model better, as indicated by a less steep trend of data points; whereas the trend of the data points for the predators is steeper and very close to the bending model. However, when we looked at those groups for which we have enough data in even more detail, we were able to spot different trends. For example, for the paddlers, the ducks, geese, and swans, we found that each of several small subgroups follow the bending model, but that the group as a whole more closely follows a compressive model.

Even though there is this diversity in our data, the broad band of points encompasses all of this diversity. This means that we may still describe an overall model for our bird data, a model that is closer to what we would expect if the bones were resisting bending more than compression. Others have found similar results. These models corroborate our interpretation of the bird femur as fulfilling its support function as a cantilever rather than as a pillar.

But still, the nagging question as to why all birds have a similar relationship between their body weight and the size of their femur and tibiotarsus persists. Why should birds that spend almost all their time in water or in the air have the same relationship as seen in terrestrial birds? The answer must lie in the *almost* of the question. *All* birds lay eggs, hence *all* birds must spend some time, however limited, on land or some other hard supporting surface. You cannot lay eggs while in flight or while swimming and expect them to produce young. And no matter how short the period of time a bird spends on land, even if it were only minutes, their legs have to support the body. If the legs were to break, the bird would die.

There is also another aspect to be considered for those birds that live almost exclusively in water. If they wish to fly, they must leave the surface of the water, which is not an easy thing to do. Land birds jump into the air to get started in flight, but it is not possible to "jump" if you are floating in water. If you watch birds taking off from water you will notice that most do so by paddling very fast while flapping their wings until they seem to be "running" on the surface of the water. Whether you are running on water or on land, the net effect is the same: the leg is

GORDON SHERMAN

Birds that take off from water, like this Northern Pintail duck, paddle very quickly while flapping their wings so that it appears that they are running on the surface of the water. Although the legs do not support all of a bird's weight on taking off or landing in water, as they do on land, they must still support a large portion of it.

supporting the weight of the bird. Also, most water birds break their landing in water by using their feet to absorb the initial impact. Water certainly does not provide as much resistance to landing birds as does land, but the resistance it does provide is significant, a fact to which anyone who has ever made an improper dive into a swimming pool can attest.

Can we ever use the data gathered from birds to predict the weights of other extinct bipedal animals? The group that immediately comes to mind is that of the bipedal dinosaurs. An attempt to predict the weight of dinosaurs using data from birds has, in fact, been made (see Anderson *et al.*, 1985). That attempt, however, was limited by the small number of birds measured (126) and the fact that the authors stated that they were unsure of the reasons why the observed relationship between leg bone circumference and body weight existed.

The largest obstacle to using the available data to predict the weights of bipedal dinosaurs is that most dinosaurs were far larger than most living birds. And as stated above, data for large living birds are extremely rare, so the prediction equation may be biased toward small animals. Before any reasonable attempt can be made to use our results to predict the weights of bipedal dinosaurs, we must have weight/skeletal data for a number of the large ratites.

There is, however, another fundamental problem that must be resolved. The point was made above that a bird's center of gravity is always located well in front of, or anterior to, the attachment of the femur to the pelvis and that to compensate for this, the femur is held in a horizontal position. It seems fairly clear from observations of the skeletons of bipedal dinosaurs that the bulk of their body, and therefore their centers of gravity, were also always found anterior to where their femora attached to the pelvis. But almost all illustrations of running bipedal dinosaurs show them with one leg extending far backward, or posterior, and the other straight under the body or also extending backward, leaving the dinosaur with no support to keep it from falling flat on its face.

Clearly there is a major discrepancy here. Either the overall shape of bipedal dinosaurs was different from what is seen in most modern illustrations of them, that is, the center of gravity was not anterior to the attachment of the femur to the pelvis, or the leg bones of bipedal dinosaurs were positioned differently than currently depicted and their method of movement was quite different.

WENDY SMITH-GRISWOLD

Left: After Osborn, H. F. 1924. *Psittacosaurus* and *Protiguanodon*: Two Lower Cretaceous Iguanodonts from Mongolia. American Musem Novitates, No. 127, Fig. 2. Right: Redrawn from left.

The small bipedal dinosaur* Psittacosaurus mongoliensis *is shown here as it was originally reconstructed, in the "normal" standing pose of bipedal dinosaurs, and in a more "bird-like" standing pose. In the original pose the center of gravity is well forward of the distal end of the femur, which would cause the animal to lose its balance and fall face-first to the ground. In the new pose the femora are in more of a horizontal position, which provides support closer to the animal's center of gravity and also drops the entire body closer to the ground. Not only would this position provide more stability to the animal when it was bipedal, the closer proximity to the ground would allow the dinosaur to scamper about using all four limbs more easily whenever it might prove advantageous. The total length of this small dinosaur was approximately 1.3 meters (4 feet).

If the former were true, then the data concerning bird weights would not be of much value in predicting the weights of bipedal dinosaurs because the forces acting on the bones would be much different, and these forces would be explained by a different mathematical equation than that which results from a study of birds.

If the latter were true, and the legs of bipedal dinosaurs were arranged more like birds and less like humans, then we could use the data from birds to estimate their weight. A hint that the legs of many bipedal dinosaurs were positioned as they are in birds comes from the fact that the shafts of their femora are arched anteriorly as in birds, which suggests a cantilever support function rather than a vertical support function as seen in quadrupeds. In the latter case the femora are much straighter, not arched anteriorly. Much more research, and data from larger birds, is required before we can be confident that predictions of dinosaur weights from birds are reliable.

So, once again the end of one small research project leads to far more new questions than were answered. How would having data on the large ratites affect the prediction equation for extinct birds? Where was the center of gravity of bipedal dinosaurs? How did the leg bones of bipedal dinosaurs line up with the rest of the body? The questions are endless. So, too, is our curiosity.

Kenneth E. Campbell is a Curator of Vertebrate Paleontology at the Natural History Museum, where he is responsible for the fossil bird and dinosaur collections. His research interests are divided between the study of fossil birds and the geological history of the Amazon Basin of South America, an area where he carries out extensive field work.

Leslie Marcus is a Professor of Biology at Queens College, New York. In his research he has worked extensively on the faunas of the Rancho La Brea Tar Pits, and his latest research there involved the radiocarbon dating of many of the localized deposits of fossil bones. He is also very active in applying new computer technology to the science of paleontology.

This article is a shortened version of a paper to be published in a volume of scientific papers emanating from the II International Symposium of the Society of Avian Paleontology and Evolution, which was hosted by the Natural History Museum in September 1988. Dr. Campbell coordinated that symposium and is currently editing the symposium volume, which will appear in late 1990 or early 1991.

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ORNITHOLOGY AND THE NATURAL LOS ANGELES COUNTY

Birds and the Natural History Museum Go Back a Long Way

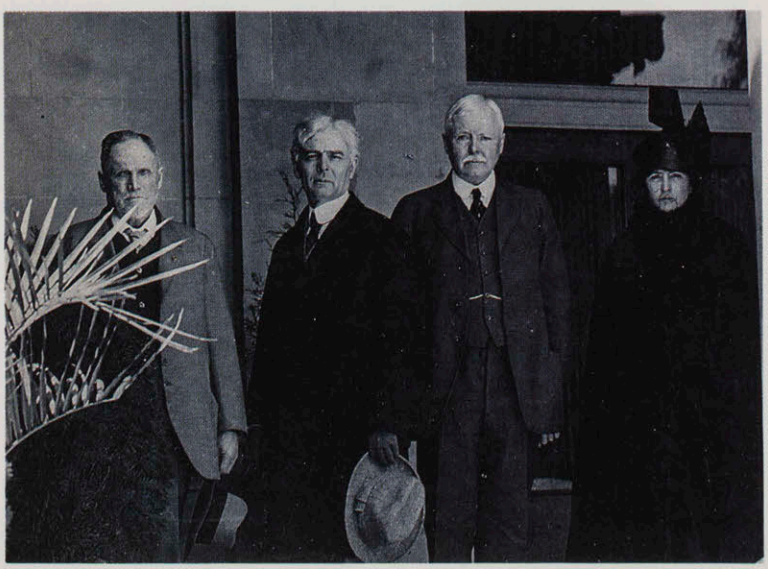
by KIMBALL L. GARRETT

Ornithology and avian paleontology have figured prominently in the history of the Natural History Museum of Los Angeles County. Four of the museum's directors, including the first, were ornithologists. The museum's collections of recent bird specimens and avian fossils are internationally significant, and the Ralph W. Schreiber Hall of Birds promises to be a world-class exhibit.

The beginnings of the Natural History Museum of Los Angeles County are tied closely to an active and exciting era in the study of ornithology in southern California. Many of the museum's first staff members belonged to the Cooper Ornithological Club, named to honor pioneering western ornithologist James G. Cooper and founded in the 1890s; the earliest ornithologists associated with the Natural History Museum were well-entrenched with the Cooper Club's Southern Division two decades before the museum was to open. Frank S. Daggett, the museum's first director, served as vice-president from 1898–1900, and as president of the division from 1901–1903; Harry S. Swarth was treasurer; Luther E. Wyman was secretary and later president. Howard Robertson, also a secretary of the Southern Division, was the Cooper Club's representative to the new museum's Board of Governors in 1910; it was in part Robertson's tireless efforts that helped establish the museum. Robertson wrote, "My dream of a museum for this city dates back to about 1900. As a member of the Cooper Ornithological Club I became aware of the need for a repository for scientific specimens—and a place where they could be studied. Individual club members were amassing separate collections which could be of only limited value—combined they could serve the entire community" (see Gretchen Sibley's article "Sixty-five and Still Growing," TERRA Winter 1978). All of these men were later to play active and important roles in the early years of what was then known as the Los Angeles Museum of History, Science, and Art.

After the groundbreaking for the new museum in 1910, ornithologist Frank S. Daggett became the institution's first director, a position he held from 1911 to his death in April 1920. With his associates from the Southern Division of the Cooper Ornithological Club, particularly Howard Robertson of the Board of Governors, Daggett helped build an ornithological presence that would continue to thrive throughout the history of the institution. In addition he brought to the museum a collection of more than 8,000 bird specimens, primarily

Frank Daggett, second from right, was the Natural History Museum's first director and was instrumental in establishing a flourishing ornithology program at the institution. He also served as president of the Cooper Ornithological Club.



NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

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from western North America.

Director Daggett persuaded Cooper Club member Harry S. Swarth to accept a position as assistant director at the new museum. Swarth had previously been associated with the Field Museum in Chicago and the young Museum of Vertebrate Zoology in Berkeley, California. After a three-year tenure in Los Angeles as Assistant Director and ornithologist, Swarth returned to the Museum of Vertebrate Zoology and later was Curator of Birds at the California Academy of Sciences in San Francisco until his death in 1935.

The May 1912 Cooper Club meeting was held at the museum (the "Museum of History, Science, and Art," as it was then known); this was the first meeting there. The meeting "adjourned to spend a very pleasant hour under the direction of Mr. Daggett inspecting the beautiful building of the museum and the very creditable work accomplished in the short time that its energetic director has been at work. Unqualified commendation was expressed by all" (from minutes of May 1912 Cooper Club Southern Division meeting, written by Loye Miller, long-time ornithologist at the University of California at Los Angeles).

The first staff ornithologist at the new museum was Luther E. Wyman, who served from 1920 until 1927. Frank Daggett had brought Wyman to Los Angeles from Chicago to work on the extensive Rancho La Brea fossils; Wyman was later appointed assistant curator. Wyman, too, was closely associated with the Cooper Club's Southern Division, having served as secretary and as president from 1924 to 1926. Wyman also made extensive local collections. He was particularly fascinated by gulls, and frequently a day's work would mean a ride down to the coast at Hyperion, in present-day El Segundo, on the streetcar (yes, Los Angeles had an efficient transit system once upon a time...) to collect gulls, and then ride back to the museum for preparation and cataloguing. The result was an important and extensive gull collection that remains a research treasure today.

William Alanson Bryan was the second ornithologist to serve as director of the museum; he succeeded Daggett in 1921 and was director until 1939, the longest period of service of any of the museum's directors. His career had included much ornithological work in the Hawaiian Islands as well as unsuccessful bids for the governorships of Hawaii and California. Bryan steered the museum through the Great Depression and presided over great increases in the exhibits and collections.

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

Preparator George Cantwell, left, skins birds with George Willett on a field trip. Willett was Curator of Ornithology from 1928 until his death in 1945.

Left: Avian paleontology blossomed alongside ornithology at the Natural History Museum and no figure has been more eminent in the field than Dr. Hildegarde Howard. Dr. Howard, shown here examining Rancho La Brea Fossils in 1939, has spent all or parts of eight decades studying paleontology at the museum.

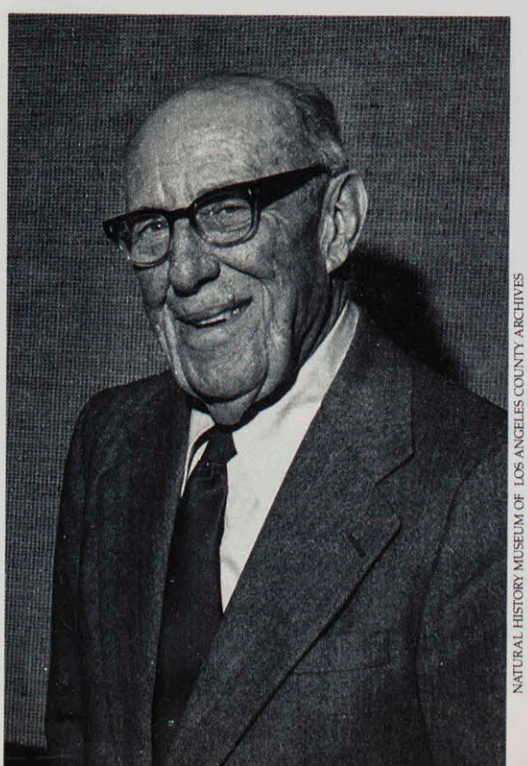
A major figure in ornithology at the museum was George Willett, Curator of Birds and head of the department of Ornithology and Mammalogy from 1928 until his death in 1945. Willett come to the museum in 1927 as assistant ornithologist under Wyman, and assumed the curatorship after Wyman's death early the following year. Willett's productivity as an ornithologist (he published over eighty papers on birds) was especially astonishing considering the considerable research and publication effort he also devoted to mollusks, particularly southern Californian land snails and fossil marine snails, through much of his career.

George Willett was an imposing man with a deep, gruff voice. As a young adult he put in time in the California National Guard, the 35th U.S. Volunteer Infantry, and in the Philippines with the Manila Police Department. After resettling in Los Angeles in 1903 he joined the Los Angeles police force, advancing to sergeant and working the Chinatown beat. Later, his fieldwork was to lead him through much of western North America and Alaska, as well as the leeward Hawaiian Islands, Mexico, and Guatemala.

Willett authored four popular museum publications on the birdlife of southern California, *Common Birds of the Los Angeles County Coast* (1942), *Common Birds of the Los Angeles County Mountains* (1943), *The Birds of the Urban Districts of Los Angeles County,* (1943), and *Birds of the Southern California Deserts* (posthumously in 1951). Late in his tenure with the museum he was instrumental in organizing and teaching natural history classes for high school students, a program that thrives today.

In 1929 a new assistant, George Cantwell, joined Willett in the curation of the ornithological collections and the preparation of specimens. Cantwell came to the museum after a long stint with the U.S. Biological Survey, and remained until 1939. In 1941 Kenneth E. Stager, who was already familiar with the museum as a student helper, joined the staff as an assistant curator, and after George Willett's death Stager became Curator of Birds, a position he held from 1946 until 1976. Stager's duties were many: and at various times he also oversaw museum expeditions, the mammal collections, and the Habitats section of the Exhibits Division. Stager received his doctorate at the University of Southern California; his research centered on food finding in vultures, and he is widely known for his demonstration of a keen sense of olfaction in the Turkey Vulture.

Under Curator Stager, a major exhibit on birds opened on the



NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

Dr. Herbert Friedmann came to the Natural History Museum from the Smithsonian Institution in 1960, serving as Director until 1970.

CLARK SUMIDA

Jean Delacour, renowned for his contributions to avian systematics, aviculture, and conservation, served as Director of the Natural History Museum from 1952 until 1960.

museum's second floor in 1948. For forty years, until its demolition in 1988 to make way for the new Schreiber Hall of Birds, this exhibit displayed the common birds of southern California grouped according to habitat along with a stunning array of waterfowl mounts and several cases devoted to bird biology.

The ornithology collections grew rapidly under Ken Stager's curatorship; several expeditions during the 1950s and 1960s, some funded by the National Science Foundation, helped nearly to triple the number of catalogued specimens in the collections. Major accessions from South America and Africa furthered the global emphasis of the collections. This boom period in ornithology was in part attributable to the fact that the museum was under the directorship from 1952 until 1970 of two well-known ornithologists. Jean Delacour accepted the position of director in February 1952 after having distinguished himself for his studies of southeast Asian birds and of avian systematics and behavior, and for his contributions to aviculture and bird conservation. Delacour's appointment came at the urging of long-serving Board of Trustees member Howard Robertson, as well as ornithologist/board members William Sheffler and Ed Harrison, at a time when the museum looked to someone of stature to direct a period of great growth. Delacour remained director until 1960, and his death at the age of 94 in 1985 marked "the end of an era in ornithology," according to noted biologist Ernst Mayr (*The Auk* 103: 603–605, 1986).

In the search for a director to replace the retired Delacour, Herbert Friedmann, Head Curator of Zoology at the Smithsonian, was asked for suggestions. He intimated he might take the job if he were younger—and the issue was settled as he assumed the directorship in 1960. Friedmann was an authority on the avifaunas of many parts of the world and was perhaps best known for his pioneering and insightful studies on brood parasitism in birds. He was also a devoted student of art history and authored numerous papers and two books on animal symbolism in art. It was during Herbert Friedmann's tenure that the Museum of History, Science and Art expanded and divided, the Exposition Park entity being renamed the Natural History Museum of Los Angeles County. Friedmann retired in 1970 and passed away in May 1987.

Ken Stager's long service as curator ended with his retirement in 1976; he has been an active Emeritus Curator since then, concentrating his studies on bats.

The collection and study of fossil

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

Dr. Kenneth Stager, Curator of Ornithology from 1946 to 1976, and a student worker unpack a collection of over 12,000 birds from Misiones Province, Argentina.

birds, particularly those found at the famous Rancho La Brea "tar pits" and other productive California sites, has been pursued actively and passionately at the Natural History Museum of Los Angeles County since the institution's founding. Pre-eminent in these studies has been Dr. Hildegarde Howard. Dr. Howard began working at the museum in 1924; she apprenticed under paleontologists Chester Stock and Loye Miller, and received her Ph.D. at the University of California, Berkeley, in 1928. Howard's scholarly work on bird fossils has continued to this day, nearly thirty years after her retirement in 1961. Kenneth E. Campbell became Curator of Paleontology in 1977 and has worked and published extensively on South American bird fossils, fossil teratorns, and size and weight phenomena in fossil birds. (See p. 32 in this issue.)

When Ralph Schreiber became Curator of Ornithology in 1976 he began an emphasis on anatomical specimens (such as skeletons and entire carcasses preserved in alcohol) as well as on the "flat" skin technique (in contrast to the traditional museum round "study" skin technique). Schreiber's studies centered around pelicans and other seabirds, and the collections of seabirds grew rapidly under his direction. Schreiber, who died in March 1988, was well-known for the long-term studies of central Pacific Ocean seabirds he conducted along with his wife Elizabeth Anne; some recent outgrowths of these studies are detailed in her article in this issue. Dr. Schreiber was president of the Cooper Ornithological Society (as the original Cooper Club has been known for many decades now) while curator at the Natural History Museum, and it was at his invitation in 1987 that the Cooper Society and the American Ornithologists' Union agreed to hold their annual meeting in Los Angeles this year.

As the 1990s begin, the relationship between the Cooper Ornithological Society and the Natural History Museum's ornithology programs remains strong. Curator Lloyd Kiff, who also directs the Western Foundation of Vertebrate Zoology, has long been an active officer of the Cooper Society. As this is written Kiff is co-chairing the local committee in charge of this summer's joint COS/AOU meeting. During this meeting, at the Annual Banquet to be held on 30 June, the Cooper Society will "come home" to the Natural Museum for an evening of celebration of the progress of our professional ornithological societies and of the Natural History Museum of Los Angeles County.

Kimball L. Garrett is Collections Manager of the Ornithology Section of the Natural History Museum.

NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY ARCHIVES

The Natural History Museum's Bird Hall as it looked from 1948 until 1988, when it was gutted to make way for the new Ralph W. Schreiber Hall of Birds.

Adventure with the MUSEUM TRAVEL PROGRAM

Santa Fe Indian Market and Pueblo Indian Feast Days
August 10–20, 1990
Indian, Spanish, and Anglo cultures remain unmerged yet firmly linked in Santa Fe. Investigate the wealth of museums, archaeological sites, national monuments, pueblos, and galleries encompassed by Albuquerque, Taos, and Santa Fe with anthropologist Kendra Bowers. Share feast-day activities in native homes and experience the world famous Santa Fe Indian Market.
$1,708 including airfare.

Peru
October 21–November 4, 1990
The majesty of Machu Picchu, the beauty of the snow-covered Andes, the colorfully clad Indians touch the senses and enrich the soul. Meet Dr. Walter Alva, discoverer of Lord Sipan's mausoleum, and famed adventurer Thor Heyerdahl at his excavation at Tucume. Journey to Colca Canyon in the Arequipa region, where there is a chance to see the legendary Andean Condors.
$3,195 including airfare

Singapore and Thailand
November 3–19, 1990
Marvel at Singapore's many cultures, then travel to Bangkok for an overview of Thailand, past and present. Shop at the colorful native market of Phitanhthai before continuing to Chaing Mai, typified by impressive mountain scenery, ancient temples, colorful hill tribes, and an amazing array of handicrafts. Visit an elephant training camp in a teak forest. Explore the 12th-century city of Sukhothai, with its immense stone sculptures of the Buddha interspersed among beautiful open courtyards.
$4,450 including airfare

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Treasures of Pre-Columbian Mexico
December 4–18, 1990
Beginning with the ancient metropolis of Teotihuacan, learn about the Olmecs, Toltecs, Teotihucanos, the Totonacs, the Mixtecs, Zapotecs, and the Aztecs. The history of these peoples covers more than 3,000 years of human development. Archaeologist Richard Hansen will be your guide through central Mexico's scenic highlands, the state of Veracruz, the spectacular ruins at El Tajin, the Aztec and Olmec sculpture in Jalapa, and in Oaxaca.
$2,741 including airfare

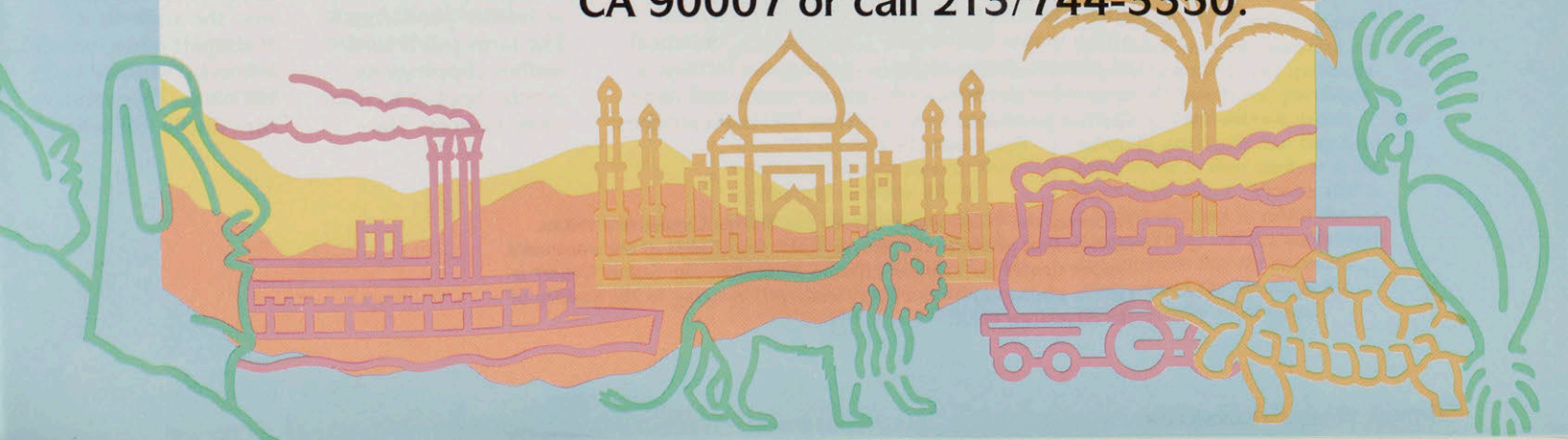
In the Footsteps of Scott and Shackleton
February 2–March 3, 1991
Set your sights on Ross Island in McMurdo Sound, as far south as any ship can possibly venture, and retrace the footsteps of early Antarctic explorers aboard the expedition ship *World Discoverer*. Sailing from Port Bluff, New Zealand, explore remote islands of the Southern Ocean via Zodiac, and visit the huts of the first explorers, preserved almost a hundred years, as well as modern Antarctic research stations.
From $12,910 plus airfare

In the Footsteps of Scott and Shackleton

Total Solar Eclipse in Baja, California
July 9–14, 1991
Astronomers and meteorologists agree: Los Cabos, at the tip of Baja California, is the ideal location to view the July 11, 1991, solar eclipse. The sun will be in total eclipse for nearly seven minutes. Our tour allows ample time to explore the fascinating botany, geology, and marine life of Baja.
$995 plus airfare

Natural Treasures of Ecuador
July 19–August 7, 1991
Our tour begins with a week-long cruise of the Galapagos aboard the 20-passenger yacht *Bartolomé*. Led by museum entomologist Julian Donahue and museum botanist Robert Gustafson, explore the Amazon River as you travel on the Rio Napo to La Selva, deep in the virgin rainforest. Also included is a visit to Cotopaxi National Park, which includes the world's highest active volcano.
$4,350 (approximate) including airfare

MUSEUM TRAVEL PROGRAM
For more information, write Karen Hovanitz, Natural History Museum, 900 Exposition Blvd., Los Angeles, CA 90007 or call 213/744-3350.



FOCUS ON THE WEST

GREENE NO. 24-29, "CAWSTON OSTRICH FARM, SOUTH PASADENA, CALIFORNIA; TWENTY-FIFTH ANNIVERSARY SOUVENIR CATALOGUE AND PRICE LIST" IN THE EPHEMERA COLLECTION, SOUTH PASADENA FILE.

Cawston's Ostrich Farm, established in 1886 and closed in 1935, was a popular South Pasadena tourist attraction and a major distributor of plumes, boas, stoles, and other ostrich feather products.

A 1911 souvenir catalogue invited visitors to "watch the whole evolution" of an ostrich "from egg to plume." The farm featured incubators, botanical gardens, a factory, a salesroom, and more than 150 live ostriches.

Once the birds were about nine months old, the Ostrich Farm considered them "ripe enough to be valuable as feather producers." The farm publicized feather clippings as events, hoping to draw more visitors. The clipping process is described in the 1911 catalogue: "When an ostrich is ready to be clipped, he is driven into the angle of a V-shaped fence, where a hood is slipped over his head. This renders him docile, for when he

Focus on the West: Images from the Seaver Center *is a* TERRA *feature that presents the photographic highlights of the museum's Seaver Center for Western History Research. The Seaver Center is rich in photographs and other materials relating to the history of the American West.*

Ostrich Feather Stoles

Black, White or Any Color

Probably in no other form are ostrich feathers developed to produce a more charming effect than in the fashionable Stole. This article is formed of two or more strands of ostrich feathers invisibly joined together to form a broad, flat effect, each strand being in reality a miniature Boa. Our Stoles are carefully made of strong, vigorous stock, most beautifully curled, and always prove satisfactory to the wearer. **For natural colors see page 11.**

No. 2025, 2 yards, 2 strands..$20.00
No. 2535, 2 yards, 3 strands.. 25.00
No. 2527, 2½ yards, 2 strands 25.00
No. 3029, 3 yards, 2 strands.. 30.00
No. 5039, 3 yards, 3 strands.. 50.00

Ostrich Feather Muffs

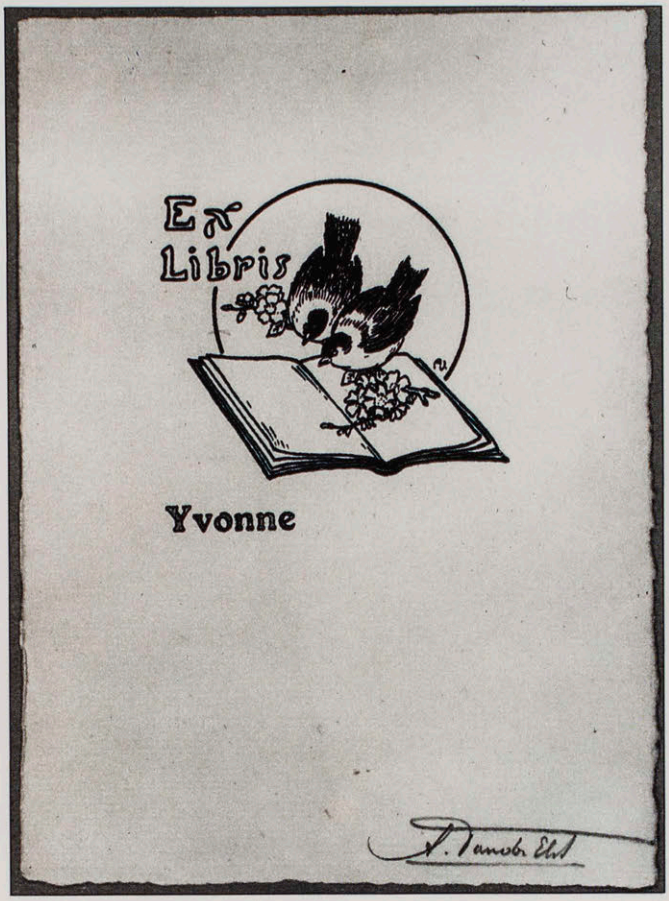
The vogue of the Ostrich Feather Muff is rapidly increasing, and its popularity is most deserved, since it combines great beauty and warmth with no suggestion of the odor which is so pronounced in furs.

Cawston Ostrich Feather Muffs are most carefully made of select stock from male birds, and are handsomely lined with a fine quality satin.

Ostrich Feather Muff, satin lined, any shade, no tails.....$30.00
Ostrich Feather Muff, satin lined, four tails, any shade.... 35.00
Ostrich Feather Muff, best grade, four tails, any shade.... 40.00

cannot see, the ostrich believes himself safe. While one man holds him, another deftly clips the plumes close to the flesh."

One of the farm's final products is shown here in a 1911 advertisement. With stoles costing from twenty to fifty dollars in that year, it's clear that the Ostrich Farm's products were luxury items produced for affluent consumers.



Q. I have discovered what appear to be several bookplates at a swap meet. Are these items of any interest to collectors?

A. According to Donald W. MacNamee, the museum's Chief Librarian, paralleling the bull market currently found in autograph collecting, other paper collectibles have also come into their own. A visit to any antique mall or to the Rose Bowl flea market, for example, offers a surprising variety of collectibles, from magazine covers to advertisements, cigar bands, orange crate labels, playing cards, postcards, books, and bookplates.

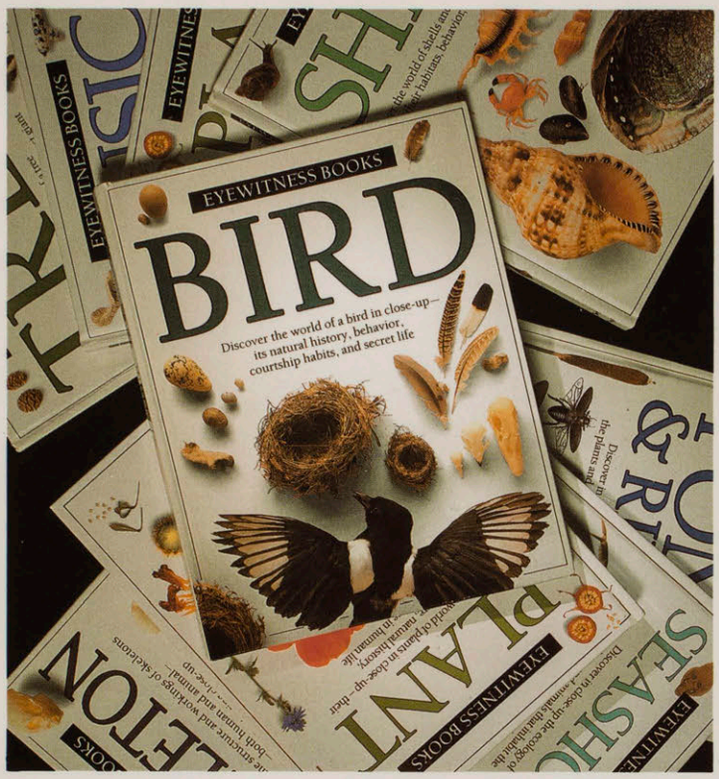
Bookplates, or printed labels used to identify the owner of a particular volume, date back to fifteenth-century Germany, but became more common in the eighteenth century. Many artists of considerable reputation, such as Thomas Bewick, William Blake, William Morris, Rockwell Kent, and Elbert Hubbard have all contributed designs for bookplates. In addition to their value as an art form, however, they are also sought after by virtue of having been the property of persons of historical or literary importance.

In the accompanying example from the Research Library's collection of 2,400 bookplates, we are not able to identify "Yvonne" or the artist "P.J."; however, the collection includes examples from the libraries of Charlie Chaplin and Edward Everett Horton and designs by Dard Hunter and James Webb.

The museum's staff members are often asked historical questions, or to identify artifacts and specimens that people have found, purchased, or inherited and animals, plants, minerals, and fossils that they have encountered in their yards or at the beach or on a hike. "Housecalls" *is a feature of* TERRA *in which the museum's staff will discuss interesting questions that the museum's members and the general public have frequently asked them.*

A Close Look
at the
Natural History of Birds

Accurate, authoritative, and beautiful, Eyewitness Books show children what other books can only tell them! Collect the entire series!



HUNDREDS of stunning photographs and lively captions present an entirely fresh look at the fascinating world of birds. Learn how birds' bodies are designed for flight, how many feathers birds have and what each one is for, and why birds make different kinds of nests.

THE AWARDS and critical acclaim continue for Eyewitness Books. Spectacular color and compelling design won this nonfiction series the Premio Grafico Fiero (first prize for graphics) at the 1989 Bologna Book Fair, and the first eight titles were named outstanding science trade books for children. *Arms and Armor, Rocks and Minerals,* and *Skeleton* were selected as 1989 IRA Teachers' Choices, and *Sports* was named an IRA-CBC Children's Choice.

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